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STRATEGIC PLANNING FOR NORTH PACIFIC SQUID DRIFTNET ENTANGLEMENT RESEARCH

Report of the
Workshop on the Biology, Oceanography and Fisheries
of the North Pacific Transition Zone and Subarctic Frontal Zone

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I. Background

A. The North Pacific Squid Driftnet Problem

In recent years, concern has increased in the United States and other countries over the effects of the North Pacific squid drift gill-net ("driftnet") fishery on populations of fishes, marine mammals, seabirds, sea turtles, and other nontarget marine resources. The squid driftnet fishery is conducted on the high seas in the North Pacific Transition Zone (NPTZ) and Subarctic Frontal Zone (SAFZ) by a fleet of approximately 700 vessels from Japan, Taiwan, and the Republic of Korea. Each year, the fishery yields about 250,000 metric tons (t) of the target species, neon flying squid, *Ommastrephes bartramii*, with a landed value exceeding US$250 million. While catching squid, however, the driftnets incidentally entangle other marine life valuable to the United States, Canada, the Soviet Union, and the squid harvesting nations themselves.

The nature, extent, and effects of this incidental entanglement are unknown. For example, of the animals caught incidentally, it is not known how many escape, drop out, or are shaken from the nets, and what proportion of these survive the encounter. Of the animals hauled aboard in the nets, little is known, even by fishery experts of the squid harvesting nations, about the kinds and number of fish, marine mammals, seabirds, sea turtles, and other animals kept as "by-catch," and the number and condition of those returned to the sea.

The concerns about incidental impacts apply to a variety of species. They include by-catch and drop-out mortality of salmon, *Oncorhynchus* spp., and steelhead, *Oncorhynchus mykiss*, of United States or Canadian origin; by-catch of Soviet salmon; mortality or net damage inflicted on albacore, *Thunnus alalunga*, escaping from the nets; mortality of the Dall's porpoise, *Phocoenoides dalli*, and the northern fur seal, *Callorhinus ursinus*; mortality of seabirds--including various species of shearwaters, *Puffinus*, albatrosses, *Diomedia*, and petrels, *Oceanodroma*--and mortality of sea turtles--including the green turtle, *Chelonia mydas*, the hawksbill turtle, *Eretmochelys imbricata*, the loggerhead turtle, *Caretta caretta*, the leatherback turtle, *Dermochelys coriacea*, and the olive ridley turtle, *Lepidochelys olivacea*.

To understand these problems better and identify the steps required for their resolution, the National Marine Fisheries Service (NMFS) Squid Advisory Committee (SQUADCOM) convened the Workshop on the Biology, Oceanography and Fisheries of the North Pacific Transition Zone and Subarctic Frontal Zone. The workshop was sponsored under the auspices of the NOAA-University of Hawaii Joint Institute of Marine and Atmospheric Research and was held at the NMFS Honolulu Laboratory during 9-13 May 1988.

The purpose of the workshop was to review biological and oceanographic information pertinent to the squid driftnet issues and to develop ideas for a strategic plan that would guide the SQUADCOM and NMFS in developing a program of squid driftnet entanglement research. Initial workshop plans called for the participation of scientists from Japan, Korea, Taiwan, Canada, and the United States so that discussions might benefit from a broad base of expertise and an exploration of ideas for international collaboration. Unfortunately, scientists from the Asian drift-netting nations were unable to attend. Participants included researchers from the NMFS Northwest and Alaska Fisheries Center (NWAFC), Southwest Fisheries Center (SWFC), and National Marine Mammal Laboratory (NMML); the Canadian Department of Fisheries and Oceans; Oregon State University; the University of Alaska; the University of Hawaii; the University of Washington; and the National Weather Service (NWS) (Appendix A).

The workshop was divided into two parts:

(1) Technical Reviews: During the first 2 days of the workshop, reports or technical reviews were presented on the history and status of the squid driftnet fishery, recent squid driftnet research by Canada and the United States, squid driftnet data base development, physical oceanography of the NPTZ and SAFZ, general biology of these zones, biology of neon flying squid, and biology of key nontarget resources impacted by squid drift-netting. These nontarget resources include marine mammals, seabirds, salmon, and albacore.

(2) Strategic Planning: During the last 3 days of the workshop, a structured planning exercise, facilitated by a professional planner, was conducted to identify elements of a research strategy, including specific projects and activities, required to meet the SQUADCOM's objectives.

This report presents the results of the workshop. First, the NMFS squid driftnet program is described. Second, provisions of a recent U.S. law pertaining to North Pacific driftnet problems is outlined. Third, the technical presentations made at the workshop are summarized (full texts of the technical papers will be compiled and published as a NOAA Technical Report). Next, the strategic planning session is described in detail and the provisional results achieved by the group are presented. Finally, a strategic plan, developed by SQUADCOM members and based on the workshop results, is described, and priorities are suggested for development of a SQUADCOM research operating plan.

B. The NMFS Squid Driftnet Entanglement Program

To deal effectively with the squid driftnet issues, NMFS must implement a balanced program of fishery monitoring, scientific research, and international diplomacy. The current NMFS "program" recognizes the importance of all three elements. However, it has provided insufficient planning, funding, staffing, and coordination to support them. This is particularly the case with monitoring and research.

On the diplomatic side, since 1986, NMFS and the U.S. Department of State have engaged Korean, Taiwanese, and Japanese Government fishery authorities in regular bilateral discussions. The objectives of these talks have been fourfold:

(1) to elicit information about the conduct of the driftnet fisheries, convey U.S. concerns about incidental mortalities, and secure relevant fishery data;

(2) to negotiate conditions for the placement of U.S. and host-country scientific observers on commercial driftnet vessels;

(3) to arrange for participation of U.S. scientists on squid driftnet surveys aboard Japanese, Korean, and Taiwanese fishery research vessels; and

(4) to seek the cooperation of drift gill-net vessels in obeying certain time-area restrictions that would minimize the incidental entanglement of U.S. salmon and steelhead trout.

The diplomatic efforts have been partially successful. In particular, the squid harvesting nations have been cooperative in allowing U.S. participation in their research vessel surveys, and have provided some information about commercial squid driftnet fishing activities. U.S. scientists participated in two squid driftnet research surveys during 1986 (Korea and Taiwan), and four cruises in 1987 (one each by Korea and Taiwan and two by Japan), and have plans to collaborate in at least two surveys in the upcoming 1988 squid fishing season (Taiwan and Korea).

In addition to collaborative research with the Asian drift-netting nations, the United States participated in surveys by a Canadian Government research vessel in 1986 and 1987 to determine the overlap in distributions of flying squid and salmonids. So far, NMFS has fielded only one survey, which used a U.S. vessel in 1987 and was aimed specifically at squid driftnet problems. Another NMFS research cruise is planned for 1989.

The research vessel surveys typically involve measurement of vertical and horizontal profiles of temperature and salinity in the squid fishing grounds, sampling of the relative abundance of squid and fish (i.e., catch rates) with gill nets, visual estimation of marine mammal, seabird, and marine debris densities along transects, observation of the behavior of marine mammals and seabirds around gill nets during gear retrievals, and collection of biological samples. Ancillary tasks may include measurement of nutrient profiles and primary productivity; sampling of plankton, neuston, or near-surface micronekton; jigging and tagging of squid; and surface longlining for larger fish species.

In contrast to the relative success of the cooperative research program, the direct assessment of incidental catch levels and other critical matters have been hampered by the lack of agreements on the placement of observers aboard commercial vessels. To date, only three U.S. observers have gone to sea on commercial squid drift-netters, two on Japanese vessels in 1982 and 1986 and one on a Korean vessel in 1988. Observer coverage of commercial drift-netting is considered the best way of estimating incidental mortality rates. If agreements cannot be reached to provide sufficient observer coverage for statistically reliable estimates of entanglement rates, other means of monitoring must be developed.

Day-to-day implementation of the U.S. program for observer placement, cooperative research, data base development, analysis, and scientific advice to negotiators has been carried out by the ad hoc SQUADCOM, made up of scientists from NWAFC, SWFC, and NMML. The SQUADCOM is coordinated by the NWAFC Auke Bay Laboratory. Funding of some SQUADCOM activities, such as salaries and travel expenses for U.S. participants on foreign research vessels, has been provided by the NMFS Marine Debris and Entanglement Research Program (MERP), administered by NWAFC in Seattle. However, the SQUADCOM has no full-time staff, and most committee work is unfunded.

C. The New Driftnet Law

In December 1987, a legal mandate for NMFS action on squid driftnet entanglement problems was established by the signing of the Driftnet Impact Monitoring, Assessment, and Control Act of 1987 (Title IV of Public Law 100-220). The "driftnet law" applies to high seas driftnet fishing that results in the taking of "marine resources of the United States" (MRUS), meaning any form of marine life found in waters subject to U.S. jurisdiction. Briefly, the law requires the Secretary of Commerce (Secretary) to do the following:

(1) negotiate with the driftnet nations to develop a cooperative program for monitoring driftnet fishing operations and assessing the numbers of MRUS incidentally killed and retrieved, discarded, or lost during fishing or hauling of the gear (drop-outs), including the provision of a sufficient number of vessels from which scientific observations can be made;

(2) conduct an assessment of the "nature, extent, and effects" of the driftnet fishery on MRUS, based on the best available information;

(3) request that governments whose driftnet vessels take MRUS provide various information essential to that assessment; and

(4) report to Congress on the outcome of the negotiations, the results of the driftnet fishery assessment, and the adequacy and reliability of the information provided by the foreign governments.

So far, there has been little administrative guidance as to how the driftnet law will be implemented. Nor have funds been appropriated for implementation, as the law provides. Meanwhile, the SQUADCOM has taken the initiative in assembling available information and preparing for provisional impact assessments. The current ad hoc arrangement is clearly inadequate, however. Greater attention must be given by top-level NMFS administrators to program planning, organization, management, staffing and funding. As a first step, strategic and operational plans that will ensure steady progress toward U.S. objectives should be developed.

D. Technical Reviews

The following summaries provide a background on several technical topics important to understanding squid driftnet entanglement problems. They are based on the presentations by workshop participants (see Appendix B) and ensuing discussions. In some instances, additional material has been added for clarification.

D-1. Physical Oceanography of the NPTZ and Associated Frontal Zones

To understand the behavior and dynamics of the flying squid gill-net fishery and its impacts on MRUS, it is essential to consider the physical oceanography of the regions where the fishery operates, the NPTZ and the SAFZ. The physical oceanographic processes have important effects on the population dynamics of MRUS species, biological production, MRUS migration and distribution dynamics, stock vulnerability, and driftnet entanglement rates.

The NPTZ is defined as a region of the North Pacific separating the cold and low-salinity Subarctic Domain and the warmer, more saline Subtropical Domain. It is an oceanwide feature associated with oceanic and atmospheric gyre macroscale circulations, spanning nearly 9,000 km between the coastal waters of Japan and North America. At midocean, its long-term average latitudinal extent is about 1,000 km.

The NPTZ is fringed on the north and south by frontal zones, namely the SAFZ and the Subtropical Frontal Zone (STFZ), respectively, in which one or more meandering fronts and frontal eddies may occur. At midocean, the SAFZ extends from about lat. 40° to 43°N, and the STFZ from about lat. 31° to 34°N. The positions of the NPTZ and its associated frontal zones do not vary by more than 150-200 km from their climatological mean positions. However, within the frontal zones, individual fronts are convoluted, meandering, and highly dynamic in time and space. For descriptive purposes, their locations can be represented by their climatological mean positions. The southern boundary of the SAFZ is marked by the Subarctic Front, with a mean position at midocean near lat. 42°N. At the northern edge of the STFZ is the Subtropical Front, at a mean midocean position of about lat. 32°N. The Subarctic Front is distinguished by the disappearance of the subarctic halocline and the overlying shallow temperature minimum, and by large changes in the hydrostatic stability structure. It is identified by the outcropping of the 33.8°/₀₀ halocline at the sea surface. A seasonal stability gap develops there in winter. The Subtropical Front is best described by the disappearance of the subtropical halocline and the surface emergence of the 35.2°/₀₀ halocline.

The nomenclature adopted here varies from that used in much of the oceanographic and fisheries literature. For example, some fishery scientists and oceanographers use the term "Transitional Domain" to refer to a region in southern subarctic waters just north of the "Subarctic Boundary," a feature identified by the outcropping at the sea surface of the 34°/₀₀ isohaline. The Subarctic Boundary is equivalent to the Subarctic

Front. The northern boundary of the Transitional Domain is defined in the literature by the emergence of the 33°/∘∘ isohaline at the surface, and this may be regarded as the northern limit of the SAFZ. Hence, the Transitional Domain is equivalent to the Subarctic Frontal Zone. Because the latter term derives from a broader view of North Pacific structure and dynamics (and not just subarctic oceanography), it may be preferable. Another term, "Transition Region," has been used to refer to the combined area of the NPTZ, SAFZ, and STFZ.

Frontal structure and dynamics of the SAFZ are considered primary factors in the aggregation of flying squid and several important MRUS and, therefore, are key determinants of driftnet effort distribution and rates of MRUS entanglement. A significant fraction of the squid catch and of MRUS incidental mortality occurs in or near the SAFZ.

On synoptic time scales, mesoscale perturbations of flow and thermohaline structure are the dominant features of the NPTZ. West of the Emperor Seamounts, the mesoscale perturbations are characterized by alternating bands of eastward and westward flows 150-300 km wide and vertically coherent in the upper 1,500 m. These perturbations are accompanied by quasi-regularly spaced thermohaline fronts. Sea surface height perturbations in this region are on the order of 0.4 m. East of the Emperor Seamounts, the mesoscale perturbations are smaller by factors of 3-6 and do not penetrate as deeply.

Seamounts in the NPTZ distort the impinging flow and generate eddies. For instance, where they pass over the Nintoku Seamount, both the Kuroshio Extension and the Subarctic Current are deflected northward, forming an omega-shaped loop over the underlying topography. In addition, the interaction of these currents with the Emperor Seamounts generates intense eddies of large amplitude but limited horizontal extent. The interannual variability of fronts also depends upon flow dynamics at particular locations. Over the Nintoku Seamount, for example, a strong thermohaline front is formed and appears to be topographically trapped, varying by not more than 50 km from its mean position at lat. 43°N during 1981-86. In contrast, about 400 km to the east, over a flat seafloor, the latitudinal position of this front varied by more than 150 km over the same time period.

The dynamics of western North Pacific waters are dictated largely by the confluence of the Kuroshio and Oyashio and are characterized by strongly defined eddies, topographical forcing due to seamounts, and quasi-regularity in meriodonal geostrophic flow. Eastern North Pacific waters are characterized by low eddy intensity, little topographical forcing, diffuse frontal structure (especially for temperature), and generally weak eastward flow.

The combined effects of large- and small-scale features of the North Pacific Ocean result in complicated circulation within the Transition Zone. From dynamic height measurements, geostrophic flow is zonal. Wind-driven (Ekman) transport can often occur at right angles to geostrophic flow, however. As Ekman transport velocities often equal geostrophic velocities in many parts of the North Pacific Ocean, both measures are needed to understand water transport adequately. More importantly, variations in wind stress, bottom topography, and boundary currents all add variability to the velocity and direction of flow patterns. As a result, the mesoscale eddy field and frontal meanders dominate both flow and the physical environment important to the ecology of marine species in this region.

D-2. The Flying Squid Fishery

Japan.--The drift gill-net fishery for neon flying squid was begun in 1978 by the Japanese. The development of this fishery coincided with reductions in other distant-water fishing grounds because of the implementation of 200-mile fishery conservation zones in the late 1970's. Although salmon catcher-boats displaced from the Japanese mothership salmon fishery were first to enter this fishery, news of their success spread quickly, causing a rapid influx of vessels from tuna and other fisheries.

Financial losses by jigging vessels (the traditional harvester of oceanic squids), in part due to the large number of drift gill-net vessels (approximately 1,000 at one point) and high catch rates by drift-netters, resulted in 1981 in the establishment, by ministerial ordinance, of an "approval" or limited entry type system and various regulatory measures to prevent the incidental catch of salmonids. These regulations established a 7-month fishing season, extending from June through December, and a northern boundary that changed monthly. Two permits for vessels between 50 and 500 gross tons (GRT) were issued one allowing 7 months of operations from 1 June to 31 December and the other allowing 4 months of operations from 1 August to 30 November.

In 1986, a total of 35,549 gill-net operations were conducted in the Japanese North Pacific squid driftnet fishery, a 9% increase over 1983. However, the number of licensed vessels has declined by approximately 5% since 1983 to 492 licensed vessels. This apparent paradox can be explained by yearly increases in the percentage of large vessels participating in the fishery. Larger vessels not only deploy more gear nightly but also have longer trips that result in a greater number of fishing operations per vessel month. Information on the total amount of gear used is unavailable.

Five different types of vessels are found in the squid driftnet fishery. The length of fishing season varies by vessel type as most vessels are committed to fish in other squid fisheries or in fisheries for salmon or groundfish. Fishing effort is usually concentrated in the upper 2° of latitude of the regulatory area. During fall, however, a number of vessels--typically the mothership or land-based salmon vessels--fish further south in warmer waters. Most gill-net operations occur between June and October, with peak effort occurring in August, the first month in which all vessel types participate in the fishery.

Generally, 450-1,100 single panels or tans of net are set daily by each vessel. Dimensions of nets are nonstandard, with a tan reported to be approximately 72-90 m in length and observed to be 40-105 m in length. The nets are all of similar design--a corkline at the surface, monofilament mesh, and a lead line at the bottom--with mesh sizes typically ranging from 115 to 120 mm. Depth of net ranges from 9 to 10 m. Single tans are tied and laced together to construct "sections" of gear approximately 3 nmi long. Two 3-nmi sections are sometimes tied together to form double-length net sections. Most of the larger vessels deploy 8-10 net sections per night.

Korea.--The Republic of Korea high-seas gill-net vessels first began harvesting flying squid in 1979. Although fishing grounds were initially located in the western North Pacific, the fishery soon extended eastward, reaching long. 160°W by 1983. The number of registered vessels grew from 14 in 1980 to 99 by 1983 and approximately 130 in 1987. Although Korea recently developed domestic regulations prohibiting the retention of salmonids and marine mammals by squid driftnet vessels, there are no time and area restrictions for this fishery.

Each year, the Korean fishery begins in late April, starting around lat. 35°N and long. 165°E. The vessels quickly move eastward to as far as long. 165°W by July, concentrating fishing effort east of long. 170°E. In early fall, the vessels move westward, fishing near the coast of Japan at the season's end in January. The late spring and summer fishery targets on the large build up of flying squid. By fall and early winter, squid west of long. 170°E have grown to a harvestable size and are caught in smaller mesh size gill nets.

Most Korean gill-net vessels are converted tuna longliners, reflecting the economic difficulties faced by tuna longliners in recent years. The converted vessels are superannuated with 90% of them 16 or more years old. Vessels range from 170 to 500 GRT with an average size of approximately 290 GRT. Mesh sizes of nets range from 86 to 155 mm, although the main sizes are 96 to 115 mm; mesh sizes are changed throughout the fishing season because of seasonal changes in the size of flying squid. Single panels (tans) of nets are 50 m long and 8 m deep. Since the start of the fishery, the average number of tans deployed nightly per vessel has risen steadily, from 200 in 1980 to 540 in 1983 and 1,000 in 1987. Little increase is expected because current Korean vessels are operating at capacity when 1,000 tans are used.

Taiwan.--The Taiwanese squid gill-net fishery began with 12 vessels in 1980, growing to over 100 vessels by 1983. Although fishing grounds were initially located in the western North Pacific, the fishery extended eastward reaching long. 160°W by 1983. Fishing has generally occurred from May through October, with peak effort in August and September.

Because of concerns of the United States about the incidental harvest of salmonids, in 1985 the Taiwanese adopted domestic regulations for squid drift-netters. In waters west of long. 170°E, fishing was prohibited north of lat. 39°N. Regulations similar to Japanese domestic regulations were adopted for waters east of long. 170°E. The most popular type of vessel is a jigging-gill-netting combination vessel. These vessel average 390 GRT and 47 m in length. They are typically converted Japanese longliners and, as such, are superannuated. During the early 1980's, nets were reported to be 50 m long, 6.5 m deep, made of monofilament vinyl chloride fibers, with a stretch mesh size of 94 mm. In recent years, mesh sizes have changed; between 1983 and 1987, the percentage of gill nets less than 100 mm rose from 18 to 44%. As with the Korean fishery, there have been yearly increases in the number of gill nets per vessel. At first, Taiwanese drift-netters were equipped with 250-500 tans of gill nets. By 1987, an average of 1,059 tans of gill nets were loaded on each vessel. This increase has effectively offset recent reductions in the the number of vessels in the fishery.

D-3. General Biology of the NPTZ and SAFZ

The large-scale oceanographic features of the North Pacific that are based on physical properties could be based also on biological and chemical oceanographic measures. Nutrient levels--such as phosphate and iron, chlorophyll a concentration, species richness, and abundance measures of plankton and zooplankton--vary in a related fashion between oceanic regions. Central North Pacific waters are characterized by very low concentrations of phosphates, low rates of primary productivity, and low abundance of zooplankton despite high species richness. Nutrient levels, primary productivity, and zooplankton abundance varies little between seasons.

Subarctic waters exhibit high nutrient levels and chlorophyll a concentrations, with high concomitant rates of primary productivity and high abundance of zooplankton. Productivity and zooplankton abundance peak during summer months, dropping to relatively low values in winter. Chlorophyll values appear to be balanced seasonally, indicating that microzooplankton quickly graze down the bursts in primary productivity.

An analysis of the geographic distribution of nekton in the North Pacific follows the general distributional patterns of the physical, chemical, and biological oceanography. For subarctic species or those species found primarily in subarctic waters, the Subarctic Boundary forms the southern limit of their distribution. Subtropical species may be found within the Transitional Domain, but they rarely range into the Subarctic Domain. Species most common in the Transitional Domain during the summer often range from subtropical to subarctic waters. For example, pomfrets, blue sharks, and saury range widely and may be caught near the Alaska Peninsula during the summer and south of the Subarctic Boundary during the winter. Little is known about the mechanisms they use to maintain themselves in this dynamic region.

Many species of nekton caught in the Transitional Domain, whether subtropical or subarctic species, feed on similar prey items. One particular prey item, *Berryteuthis anonychus*, can be found in the stomachs of pomfrets, salmonids, flying squid, and albacore.

D-4. Biology of Flying Squid

A considerable body of literature has been published on the North Pacific population of the neon flying squid. Most available information on the neon flying squid is based on data collected from commercial fishing vessels. As a result, information on the species is restricted to the population available within the pelagic fishing zone.

The neon flying squid is an oceanic species distributed in temperate and (primarily) subtropical regions worldwide. The species is broadly distributed across the North Pacific between the Equator and approximately lat. 50°N. Distribution is strongly correlated with sea surface temperatures within the 15°-24°C (July and August) and 10°-22°C range (September-December). Extensive seasonal migrations take place in May and June, between the winter spawning concentration areas in the Subtropical Domain and the summer and fall feeding grounds along the Subarctic Boundary and in the SAFZ. Northerly movements in the western North Pacific follow the Kuroshio and its associated fronts; southerly movements occur ahead of the expanding cold Oyashio. Although seasonal migrations occur simultaneously in the eastern North Pacific, their relationship to temperature and current structures have not been well described.

Vertical distribution of neon flying squid varies with water temperature, salinity, current mixing, and probably availability of prey. Although individuals have been found at considerable depth, the limits of vertical distribution are strongly associated with the 10°C isotherm, which usually occurs at a depth less than 70 m and again between 100 and 200 m within the Kuroshio. Distribution from summer through early winter is primarily in the upper surface waters warmer than 10°C. Like other members of the Ommastrephidae, the neon flying squid undergoes diel vertical migrations.

All males and most females mature, spawn, and die within 1 year. Some females live for nearly 2 years, delaying spawning until their second season. An extended spawning period with two peaks (January-February and April-May) produces what have been interpreted as distinct cohorts. The recruits to the fishery, therefore, appear as groups of "large" and "small" squid. Preliminary tagging studies indicate highly variable growth rates between the large and small cohorts. Growth rates are high in spring and summer during northward migration (2.0-4.0 cm/month) and slow with approaching sexual maturity in late fall and winter (0.5-2.0 cm/month). The dorsal mantle length of squid caught in gill nets and on jigs throughout the North Pacific ranges between 14 and 50 cm and averages 27 cm.

Male neon flying squid mature sooner and are smaller at maturity than are the females. Males show the first signs of spermatogenesis at a mantle length of 28.5 cm and body mass of 670 g. All males are fully mature by November or December, at a mantle length of 32.5 cm, testis weight of 15-20 g, and body mass of approximately 1 kg. Based on the presence of spermatophores, females in the western North Pacific mature during January or February at a dorsal mantle length of 40 cm and ovary weight of 20-50 g. First signs of maturity in females from the central Pacific have been reported at 50 cm dorsal mantle length. Some evidence indicates that squid reach a larger size at maturity in the central and eastern Pacific than in the western North Pacific. There also may be different stocks in the two areas.

Stomach samples examined from squid collected in the western North Pacific south of the Subarctic Boundary contain primarily fishes and secondarily squid. Fishes include lanternfishes, sardines, juvenile mackerel, and saury; identified squids are Watasenia scintillans, Onychoteuthis borealijaponica, and (cannabilized) Ommastrephes bartramii. Planktonic crustaceans (e.g., Euphausiacea and Parathemisto spp.) also are occasionally represented in low numbers in stomach contents and are found in the greatest proportions in young squid.

D-5. Biology of Marine Mammals

Five important marine mammal species are caught in the North Pacific high-seas squid driftnet fishery: northern fur seals, Dall's porpoises common dolphins, northern right whale dolphins, and Pacific whitesided dolphin. Of these, the northern fur seals have been most extensively studied and provide the best opportunity for quantifying the effects of incidental take on population abundance.

Northern fur seals are solitary at sea; seldom, if ever, are more than one or two seals observed per square km of ocean surface. Fur seals (and Dall's porpoises) typically forage on prey 8-10 cm long, and observations near breeding areas have identified two types of feeding behaviors. The most efficient but least used behavior consists of a regular pattern of 5-minute-long dives, each over 200 m in depth and followed by a 20-minute resting period. After approximately 3.5 hours of feeding, the animal rests for 3 hours before beginning the feeding period again. A second and more commonly used behavior occurs near the shelf break and in offshore waters. The fur seals begin feeding near dusk and dive to about 100 m; diving is relatively continuous and occurs without long resting periods. As the night progresses, the depth of diving decreases, then increases towards dawn, when the feeding stops. In a single night, about 300 dives are made.

Although fur seals are found in sea surface temperatures ranging upwards to 14°C, they usually are found in waters 8°-13°C, according to records of pelagic sealers. These temperature preference patterns closely follow those of Dall's porpoises and preliminary data suggest that they are quite different from those of northern right whale and Pacific whitesided dolphins.

D-6. Biology of Seabirds

Information on the distribution, abundance, and ecology of seabirds in the NPTZ and SAFZ has been collected during sighting surveys aboard merchant ships ("ships of opportunity") and from observations aboard commercial or research squid drift gill-net vessels. Entanglement data have been gathered mostly from squid research vessels. The effort expended in these surveys has been insufficient to describe species distribution and abundance patterns adequately and to permit reliable estimates of entanglement rates. Most available data have been collected during summer surveys in the north-western part of the flying squid fishing grounds; less is known about distribution and the entanglement rates during the fall months and over other regions of the fishery.

Surveys during the summer months of highest driftnet effort have identified 34 species of seabirds in the region of the squid driftnet fishery. Both tropical/subtropical and subarctic forms have been identified, with the SAFZ being the region of overlap dividing the two avifaunas. Of the 34 species, 8 are common in the squid fishing area: black-footed albatross, Diomedea nigripes; mottled petrel, Pterodroma inexpectata; Buller's shearwater, Puffinus bulleri; sooty shearwater, P. griseus; fork-tailed storm petrel, Oceanodroma furcata; Leach's storm petrel, O. leucorhoa; and red phalarope, Phalaropus fulicarius.

During fall surveys, 29 species have been recorded in the flying squid fishing grounds; these include many of the species encountered on summer surveys as well as several subarctic species (e.g., common loon, Gavia immer; glaucous-winged gull, Larus glaucescens; black-legged kittiwake, Rissa tridactyla; and Cassin's auklet, Ptychoramphus aleuticus. Fall sampling has been less extensive, however, covering only the northeastern sector of the squid fishery; NPTZ and SAFZ waters have not been surveyed during the fall.

Species distribution shows latitudinal zonation of habitats within the region. Mean aggregate seabird density (based on counts) also varies with latitude; it is highest in subarctic waters, intermediate in the SAFZ, and lowest in the NPTZ waters. Presumably, this variation in mean seabird density is directly related to differences in biological productivity among the oceanic regions.

Of the 34 species seen during the summer, 13 are tropical/subtropical and 16 are subarctic, but some species in each group may range into the SAFZ and even into the other group's principal habitat. Another species, the Leach's storm-petrel, has breeding populations in both the subarctic and the tropics and has members that may overlap in the SAFZ. Two species, the flesh-footed shearwater, Puffinus carneipes, and the south polar skua, Catharacta maccormicki, appear to occur mainly in the SAFZ. One species, the black-footed albatross, was observed with equal frequency in all three oceanic zones.

Of the six species most frequently entangled in the squid driftnets, three breed in the North Pacific (Laysan albatross, Diomedea melanophrys; tufted puffin, Lunda cirrhata; and horned puffin, Fratercula corniculata), and three breed in the South Pacific (flesh-footed shearwater; sooty shearwater; and short-tailed shearwater, Puffinus tenuirostris).

Seabird entanglement rates in squid driftnets are affected by species behavior and feeding habits. The albatrosses are strongly attracted to squid fishing operations and actively feed on squid and fish caught in the gill nets up to 1.5 m below the sea surface. The northern fulmar, Fulmaris glacialis, and the shearwaters are shallow divers and feed on squid and fish caught in the nets down to a few meters below the surface, as well as on offal discarded from squid vessels. Several other species may be attracted to fishing operations and offal, but they appear not to feed directly from the nets and therefore run a lower risk of entanglement.

The number of seabirds attracted to a driftnet appears to be directly (but nonlinearly) related to the length and soak time of the gear. Entanglement rates appear to depend on bird density in the fishing area and are extremely variable, because of the patchy at-sea distribution of seabirds. The risk of entanglement probably increases during periods of migration, when more birds are exposed to the gear set in an area (such as the September-October southward migration period for sooty and short-tailed shearwaters).

D-7. Biology of Albacore

Albacore occur in the North Pacific between lat. 10° and 50°N and support directed fisheries by several types of vessels: U.S. trollers, pole-and-line (live bait) boats, and recreational rod-and-reel boats; Canadian trollers; Japanese longliners, pole-and-line boats, and large-mesh (Ome-ami) drift gill-net vessels; Korean longliners; and Taiwanese longliners. The maximum sustainable average yield for the resource is estimated to be 85,000-135,000 t/year. In 1985 the catch from directed fisheries was approximately 60,000 t, with the U.S. share amounting to about 9,000 t. Albacore also are taken incidentally by squid drift gill-net vessels from Japan, Korea, and Taiwan, but the magnitude of this incidental catch is unknown.

The distribution of albacore is age- and size-dependent, with spawning fish occurring predominantly west of the Hawaiian Islands between lat. 10° and 20°N (south of the Subtropical Convergence Zone) and subadults being found generally between lat. 30° and 50°N (NPTZ and SAFZ). Tagging studies have shown that the subadults make extensive seasonal migrations. In particular, transpacific migrations occur; therefore, there is a potential for significant interactions between the Japanese fisheries in the western Pacific and the North American fisheries in the eastern Pacific. Further, studies of the subadult albacore suggest that two stocks may exist within the region and have different growth rates and migration patterns.

The subsurface longline gear harvests mature and subadult fish, whereas the surface-fishing trollers, pole-and-line, and Ome-ami vessels catch primarily the subadult albacore. The surface fisheries generally take albacore in waters with a temperature of 15°-19°C, and are most effective where there is a shallow mixed layer and the fish are aggregated near temperature fronts or other boundary features. Ultrasonic tracking of free-swimming albacore carrying depth and temperature sensors has shown that albacore spend considerable time swimming in or near the thermocline in temperatures as low as about 10°C, however. Albacore also have been taken in squid drift gill nets set in water as cold as 10°-11°C.

Albacore distribution and catchability are markedly influenced by oceanographic conditions, particularly the oceanic frontal structure. Fishing grounds and conditions are routinely forecast by using information on sea surface temperature and frontal structure derived from satellite imagery. For thermal fronts in the SAFZ, albacore aggregate on the warm (subtropical) side of the fronts to feed opportunistically on cephalopods, fishes, and crustaceans that are concentrated there. In the frontal region between NPTZ waters and California Current waters, studies using satellite ocean color imagery and concurrent observations from sonic-tagged albacore, research vessels and commercial fishing logbooks have suggested that water clarity also is an important factor in the distribution of albacore. Albacore concentrate in the warmer, clearer subtropical waters along upwelling fronts and avoid areas of apparently higher productivity and prey density in the colder (but not unacceptably cold) and more turbid California Current waters.

D-8. Southern Distribution of Salmonids

Until recently, only sporadic and limited work had been done to identify factors affecting the southern distribution of salmonids during their residence period in the North Pacific Ocean. Most of these studies focused on the relationship between salmonid catch rates and sea surface temperature, and the distributional overlap of flying squid and salmonids. These studies showed that (1) the distributions of flying squid and salmonids overlap to some degree and (2) catch rates of salmonids are relatively low where sea surface temperatures are higher than 15°C, whereas catch rates of flying squid drop off sharply in waters colder than 12°C. In recent years, sufficient data have accumulated to allow improved insight into factors affecting the southern distribution of salmonids. In particular, the individual and combined effects of sea surface temperature and geographical location (longitude and latitude) are now better understood.

Data from 23 research vessel cruises occurring in 1982-87 were divided into two geographical regions (160°E-175°W and 174°-145°W, hereafter called the western and eastern regions, respectively) based on similarity of physical oceanographic characteristics. Within these two areas, the data were further divided into three sea surface temperature intervals (10.0°-12.9°C; 13.0°-15.0°C; and 15.0°C or warmer) and limited to those gill-net operations occurring within the northernmost 0.5° latitude of the squid regulatory area (as defined by Japanese domestic regulations).

Salmonid occurrence (the proportion of gill-net sets in which salmonids were caught, weighted by length of the net) west of long. 175°W was 47%, but only 8% east of long. 175°W. The longitudinal cline in salmonid incidence persisted even when the data were stratified further by sea surface temperature interval. Forty-one percent of the gill-net sets in the western region of the squid fishing area, and in sea surface temperatures of 13°-15°C interval, caught salmonids compared with 0.0% in the corresponding eastern area. Where the sea surface temperature was colder than 13°C, salmonids were taken in 72% of the gill-net sets made in the western region, but only 19% in the eastern area.

There is growing evidence that salmon primarily inhabit subarctic waters and seldom migrate into the Transitional Domain (or the northern portion of the SAFZ), thus confirming the importance of water mass structure in determining the southern limit of salmonid distribution. For instance, Japanese scientists have shown, in an analysis of meridional transects across the SAFZ, that salmon catches in most transects were confined to subarctic waters; otherwise, they occurred in the northernmost portion of the SAFZ.

Geographical differences in the relationship between catch per unit effort and sea surface temperature are easily explained if water mass structure is an important determinant of the southern limit of salmonid distribution. Although sea surface isotherms are generally zonal across the North Pacific Ocean, the SAFZ is located 4-6 degrees further north in the eastern region than in the western area. Because of this angling northward, when the sea surface temperature is colder than 15°C in the squid fishing region, subarctic water intrusions, as defined by the subsurface thermohaline structure, are less likely to occur in the eastern area of the fishery than in the western area.

II. Strategic Planning

A. Purpose, Method, and Roles

The purpose of the strategic planning meeting was to develop the main features of a 5-year research program plan for the SQUADCOM that would guide its short- and long-term programming, scheduling, and budgeting decisions. The emphasis was on identifying major concerns and considerations with respect to the various MRUS affected by squid driftnets, and the basic elements of a scientific research program to achieve SQUADCOM goals. The strategic plan then would provide a basis for more detailed and specific operational planning by the SQUADCOM and its collaborators, consistent with funding constraints. The plan also would assist NMFS in undertaking a more fundamental evaluation of agency goals and programmatic actions with respect to squid driftnet issues.

Incidentally, the workshop was seen as a way to establish a network of scientists from universities and government agencies with expertise and interest in various aspects of the squid driftnet problem. Such a network would be a valuable basis for future collaboration in SQUADCOM research programs.

The strategic planning was carried out by employing a facilitated, interactive planning system involving a set of consensus-building techniques. The interactive planning method helps a group of people from different backgrounds--and with different areas of expertise, perspectives, and viewpoints--arrive efficiently at a consensus on issues and appropriate solutions (if a consensus, in fact, exists) by a professional planning facilitator. The method stresses the active and equal participation by all group members, so that the resulting plan reflects the full spectrum of ideas and concerns. The role of the group members is to provide the content of the plan, based on their scientific or administrative expertise and experience. They provide information to each other, offer ideas about research projects and activities in response to probing by the facilitator, explain and clarify their ideas to the other members, and indicate their preferences and priorities for multiple alternative research strategies. The role of the facilitator is to establish the format and ground rules of the planning process and to maintain fair and orderly progress toward plan development.

B. Objectives of the SQUADCOM

The planning session began with the definition and clarification of the objectives of the SQUADCOM. These objectives had a basis in the new driftnet law and were as follows:

(1) estimate the number of MRUS killed in the North Pacific squid driftnet fishery;

(2) determine the effects of this fishery on the MRUS; and

(3) develop and evaluate management options for mitigation of the impacts on MRUS.

The first and second objectives respond to requirements under Section 4005 of Public law 100-220, specifically the requirement that the Secretary of Commerce report to Congress on the "nature, extent, and effects" of driftnets on MRUS. The report is to be based on the best available information, including data derived from shipboard monitoring programs undertaken by the United States in cooperation with the relevant foreign governments, as provided for in Section 4004, or statistics supplied by the foreign governments at the request of the Secretary, as stipulated in Section 4005. The Secretary also must evaluate and report on the reliability of the information provided by the foreign governments. Although the driftnet law does not define the meaning of "effects," the planning group understood the word to mean the biological and ecological impacts on MRUS and related economic impacts.

The third objective has no foundation in the driftnet law; however, it anticipates the need for a quantitative evaluation of driftnet fishery management options. The development and analysis of management options are essential for negotiated agreements on measures to reduce the detrimental effects of squid driftnets on MRUS.

C. Defining the Elements of a Research Program

With the SQUADCOM's objectives defined, the planning group was asked to participate in a Nominal Group Technique (NGT) session by responding to the following "trigger question":

"In the context of producing a research plan for the SQUADCOM, what important projects or major tasks do you think need to be carried out to meet the program objectives by 1994?"

Each member independently drew up a list of projects, and the lists were compiled; 61 projects were proposed. Then each suggestion was explained and clarified by its originator, until the group understood its meaning. As the projects were reviewed, some were modified or elaborated, some were combined with others, and a few new ones were added to the list. The final list of 63 projects is given in Appendix C.

Then each group member contemplated the list of 63 projects and independently selected and ranked the 5 projects that they considered most important. These results were tabulated, with seven projects receiving at least one top ranking (and usually several other high rankings). The following projects were considered "most important" by the group:

Project 4--Develop sampling design, sampling protocols, and an operational plan for an observer program to collect oceanographic, biological, and by-catch data.

Project 7--Understand biological and oceanographic processes affecting the distribution, abundance, and availability of MRUS and their associated catch rates in the driftnet fishery.

Project 14--Develop models of squid population dynamics.

Project 16--Understand the effects of mesoscale physical and biological processes on the distributions of important MRUS affected by the squid driftnet fishery.

Project 20--Define the means of implementing the observer program.

Project 27--Develop research program options, including research vessel plans, to estimate total incidental mortalities in the absence of adequate observer agreements.

Project 43--Develop models to predict by-catch under various scenarios of the squid driftnet fishery.

Although these 7 projects were clearly seen as the most important, 23 other projects were ranked at least once among the top 5.

Next, the participants explored the interrelationships among the projects, starting with those of highest rank. This process was aided by another interactive, consensus-building technique, in this case employing a computer program called Interpretive Structural Modeling (ISM). Prompted by the program, the planning group answered the following question with respect to each pair of projects selected by the program (denoted X and Y):

"In the context of pursuing the research program objectives, will the experience or information from project X be needed to carry out project Y?"

This exercise produced a structural map and flowchart showing the support relationships among the projects. The inferential logic algorithms of the ISM program minimized the number of pair-wise comparisons required to describe the structure. Nevertheless, in the several hours scheduled for the ISM process, only 21 of the projects could be discussed and examined by the group, yielding a preliminary and incomplete structure. This was a very useful result, however, and included all of the key, high-ranking projects. Later, members of the SQUADCOM completed the ISM task.

D. The Prelimary Program Structure

A flowchart showing the preliminary program structure developed by the entire planning group is given in Figure 1. Two features of the first-cut program structure stand out. First, even with a subset of projects defined at a high level of organization, the complexity of the driftnet program is evident. Second, it is not yet clear from the preliminary structure how the projects support the SQUADCOM goals. Only project 14 (develop models of squid population dynamics) is in a terminal position in the flowchart, suggesting that all other projects must precede it or that they support no other useful objective. Clearly, this is not what the planning group intended.

Another reason for ambiguous results in the ISM structuring is that semantic differences colored the group's collective responses. The Nominal Group Technique (NGT) and ISM methods at once clarify and confound a group's thinking about a problem by exposing the myriad ways different people can view the same word, concept, or statement. Ambiguity apparent in the preliminary program structure sometimes can be resolved in later iterations. Indeed, without some formal process to expose these "disconnects" between participants, it is entirely likely that group members would leave the meeting thinking that they are understood or that they understand each other's ideas perfectly, when in fact confusion still reigns.

In this case, the group repeatedly was divided on the meaning of the concepts "model" and "modeling." Some members of the group saw a "model" as a refined numerical end product of research, and "modeling" as the ultimate analytical activity necessarily preceded by hypothesizing, survey planning, and data collection. Others viewed "modeling" as a process that began with the first thought about a problem (the first conceptual "model") and continued through iterations of hypothesizing, experimentation, and analysis until some conclusion was reached. Some vaccilated between views, depending on the project comparison under consideration.

This ambiguity is reflected in the preliminary program structure. For example, Figure 1 shows that the group considered projects 16 and 43 to be mutually supportive. The group thought that knowledge of mesoscale physical and biological processes and their effects on MRUS distributions would be useful for prediction of by-catches. At the same time, at least a provisional conceptual model of by-catches would be needed to indicate how information on MRUS distribution and mesoscale effects would be employed.

It is important to bear in mind when interpreting the flowchart that the indicated relationship between a pair of projects is not necessarily a temporal one. That is, project X may support project Y (in the sense of the question above) without having to precede it; in fact, many of the "projects" would be concurrent and would involve feedback relationships characteristic of iterative, adaptive processes.

E. Tasks and Activities

After developing the preliminary (and incomplete) program structure, the group was asked to specify the tasks and activities it thought were required to achieve the 21 projects included so far. Because little time was available for this exercise, a complete specification of tasks was impossible. However, even the incomplete results will assist the SQUADCOM in later development of operational plans.

To simplify the process, the projects were placed in four categories: (1) biology, (2) oceanography, (3) fishery monitoring and analysis, and (4) administration. Several of the projects fell in more than one category:

	Category			
Project	Biology	Oceanography	Assessment	Administration
1			X	
2				X
4		X	X	
5			X	
6	X		X	
7	X	X		
9	X			
12	X			
13		X		
14	X		X	
15				X
16		X		
18	X			
19	X			
20			X	
22	X	X	X	
23		X		
24	X			
27			X	X
37	X	X		
43			X	

The participants assembled into subgroups, and each subgroup dealt with a specific category of projects. The results of this exercise are listed in Appendix C.

III. Follow-up Work by the SQUADCOM

A. Revised Strategic Plan

The preliminary program structure shown in Figure 1 shows a rich set of ideas for achieving the SQUADCOM's goals and reveals the complexity of relationships among them. However, further work was needed (1) to complete the ISM process begun by the entire planning group and (2) to clarify and simplify the program strategy and produce a plan more understandable by people outside the planning group.

First, the SQUADCOM completed the ISM process on the remaining projects. This additional work resulted in the chart in Figure 2. This figure provides a somewhat better view of the overall program strategy than does Figure 1, but it still lacks clarity.

Next, the SQUADCOM reworked the program structure in an effort to simplify the strategy and its graphical presentation. This reworking was accomplished by aggregating the projects generated by the NGT process into higher order elements, while explicitly showing how these major elements of the strategy supported SQUADCOM goals. All projects suggested by the workshop group were retained somewhere in the strategy within a higher order element, with the exception of projects 44 and 50, which pertain to marine debris.

The simplified plan, which is displayed in Figure 3, shows more clearly the key program elements and strategies. The elements are shown arrayed from left to right, with arrows indicating primary links between them. The steps lead logically to the SQUADCOM goals on the far right.

Beginning on the left of the flowchart, some key administrative elements are as follows:

(1) Development of an administrative structure for the program, including adequate staffing, funding, and management.

PROJECT: 2

(2) Development of a comprehensive data base to support the systematic editing, storage, retrieval, and analysis of squid driftnet information.

PROJECT: 39

(3) Creation of a coordinating body of government, university, and industry experts to advise the SQUADCOM, or its successor organization, on the development and integration of a research program supporting the program goals.

PROJECT: 15

(4) Continued support of bilateral talks between the United States and nations with drift gill-net fleets to acquire driftnet effort and entangle-

ment data and to arrange for placement of U.S. observers on commercial driftnet vessels and/or research vessels for estimation and monitoring of driftnet entanglement rates. [Note: this element was not among those generated by the trigger question.]

PROJECT: new project added by SQUADCOM

The next set of program elements involves development of operational plans and assessment guidelines and management of data collection tasks:

(1) Development and management of the observer program to collect data from commercial squid driftnet vessels, including recruitment and training of observers, standardization of data collection forms and procedures, and evaluation of observer placement goals and strategies.

PROJECTS: 4, 20

(2) Identification and acquisition of existing data pertaining to squid driftnet effort and entanglement rates through the bilateral talks or other means.

PROJECT: 33

(3) Development of research programs, including research vessel surveys, necessary to achieve the program goals and particularly to enable the estimation of entanglement rates and driftnet impacts in the absence of an observer program.

PROJECT: 27

(4) Development of the means of evaluating impacts of incidental mortalities of MRUS, including (a) definition of criteria for measuring effects on the MRUS stocks, associated biological communities, and ecosystems, and on people who benefit from them (i.e., socioeconomic impacts); (b) agreement on methods of computing such effects; and (c) setting of tolerance limits or acceptance levels for the various impacts.

PROJECTS: 38, 49

A third category of program elements covers the various research activities, including analyses of existing data and collection of new data from research vessels:

(1) Biological studies of MRUS species and relevant ecosystems, including descriptions of the distribution and migration patterns of marine mammals, seabirds, salmonids, and albacore, and the relationships between these patterns and oceanographic parameters (such as frontal structure and sea surface temperature). Of particular importance is the delineation of the southern distribution of salmon and steelhead stocks with respect to near-surface temperature structure.

PROJECTS: 12, 19, 23, 24, 29, 30, 36, 37, 42, 51, 52

(2) Studies of physical, chemical, and biological oceanographic processes important to an understanding of the dynamics of the squid driftnet fishery and the stock abundance, distribution, and catchability of MRUS.

PROJECTS: 3, 13, 25, 35, 54, 55, 61

(3) Studies specifically focusing on mesoscale ocean structure and dynamics and their relationships to variability in the incidental mortality of MRUS.

PROJECTS: 16, 17

(4) Studies of the variability in stock sizes of important MRUS and the causes of such variation, for evaluating trends in MRUS populations and for documenting impacts of incidental mortality in the squid driftnet fishery.

PROJECTS: 9, 31, 58, 59

The biological and oceanographic studies support another set of elements aimed at modeling the basic components of numerical models for estimation of entanglement rates:

(1) Development of models of flying squid population dynamics (abundance and distribution).

PROJECTS: 14, 22, 34, 41

(2) Modeling of squid driftnet fleet dynamics (fleet size and distribution), based on squid stock dynamics and economic factors.

PROJECTS: 1, 40, 46, 62

(3) Modeling of MRUS stock densities and catchabilities on the squid fishing grounds.

PROJECT: 7

Finally, a set of program elements leading directly to the three major goals was identified:

(1) Development of models and methods for monitoring and predicting squid driftnet incidental mortality levels, based on lower level components.

PROJECT: 43

(2) Development of methods, regulations, and policies to reduce entanglement rates and incidental mortality of MRUS.

PROJECTS: 21, 48, 60

(3) Development of models and methods to monitor and predict impacts of squid driftnet incidental mortality on MRUS and associated socioeconomic (user) values.

PROJECT: new project added by SQUADCOM

On the right-hand side of Figure 3, the three SQUADCOM goals are given. They are supported by the lower level elements. In addition, they directly involve several projects not included elsewhere:

(1) Estimate and report on the nature and extent of incidental mortality to MRUS caused by squid drift gill nets.

PROJECTS: 5, 6, 10, 18, 26

(2) Assess impacts of incidental mortalities on MRUS populations and associated socioeconomic (user) values.

PROJECTS: 47, 63

(3) Evaluate management options.

PROJECTS: none suggested yet

Although the arrows in Figure 3 suggest the major logical and support relationships between the program elements, the left-to-right arrangement of components is not meant to imply a temporal ordering. In fact, many of the projects would be concurrent and would involve feedback.

B. Implementation

This strategic plan will be used to guide SQUADCOM activities and to give direction to driftnet entanglement program development decisions at higher levels of NMFS.

Two steps will be taken to move forward with planning:

(1) The strategic plan will be circulated within NMFS and presented to NMFS administrators at headquarters and the regional levels for information and action.

(2) The SQUADCOM and scientists at regional laboratories involved in the driftnet research program will develop operational plans to address key national and regional concerns, assisted by the extensive list of tasks and activities suggested by workshop participants. The various operational plans, appropriately coordinated, will provide a basis for comprehensive driftnet program funding decisions.

APPENDIX A

List of Workshop Participants

Peter J. Celone (*)	National Weather Service Honolulu, Hawaii
James M. Coe	Northwest and Alaska Fisheries Center National Marine Fisheries Service Seattle, Washington
Robert H. Day	Institute of Marine Sciences University of Alaska Fairbanks, Alaska
Roger L. Gentry	National Marine Mammal Laboratory National Marine Fisheries Service Seattle, Washington
Michael Henderson	Department of Fisheries and Oceans Biological Sciences Branch Vancouver, B.C., Canada
Steve E. Ignell	Auke Bay Laboratory National Marine Fisheries Service Auke Bay, Alaska
Linda L. Jones	National Marine Mammal Laboratory National Marine Fisheries Service Seattle, Washington
R. Michael Laurs	Southwest Fisheries Center National Marine Fisheries Service La Jolla, California
Ronald Lynn	Southwest Fisheries Center National Marine Fisheries Service La Jolla, California
Leo Margolis	Department of Fisheries and Oceans Biological Sciences Branch Pacific Biological Station Nanaimo, B.C., Canada
Russell E. Nelson, Jr.	Northwest and Alaska Fisheries Center National Marine Fisheries Service Seattle, Washington

William G. Pearcy	College of Oceanography Oregon State University Corvallis, Oregon
Gunnar I. Roden	School of Oceanography University of Washington Seattle, Washington
Richard S. Shomura (*)	Honolulu Laboratory National Marine Fisheries Service Honolulu, Hawaii
Elizabeth J. Sinclair	Oregon State University Corvallis, Oregon
Jerry A. Wetherall (convenor)	Honolulu Laboratory National Marine Fisheries Service Honolulu, Hawaii
Richard E. Young	Oceanography Department University of Hawaii Honolulu, Hawaii
David J. Mackett (facilitator)	Southwest Fisheries Center National Marine Fisheries Service La Jolla, California
Susan Jacobson (assistant facilitator)	Southwest Fisheries Center National Marine Fisheries Service La Jolla, California

*Participated in technical session only.

APPENDIX B

Workshop on Biology, Oceanography and Fisheries of the North Pacific Transition Zone

9-13 May 1988

Conference Room
Honolulu Laboratory, Southwest Fisheries Center
National Marine Fisheries Service
2570 Dole Street, Honolulu, Hawaii

SCHEDULE AND AGENDA

<u>Monday, 9 May</u>
9:00 a.m. - 4:30 p.m.

(1) Introduction (J. Wetherall)

* background and scope of workshop
* objectives, timetable
* review of agenda

(2) Review of squid driftnet fisheries -- catch, effort by time & area; historical data, trends, current status; regulatory process (S. Ignell)

(3) Overview of recent research programs

* U.S., Japan, Korea, Taiwan (S. Ignell)
* Canada (R. Margolis)

(4) Review of data base -- fishery statistics & research vessel data

* inventory, data base description (J. Wetherall)

(5) Review of Transition Zone oceanography (G. Roden)

<u>Tuesday, 10 May</u>
8:30 a.m. - 5:00 p.m.

(6) Review of Transition Zone biology

* General (W. Pearcy)
* Flying squid (E. Sinclair)
* Marine nammals (R. Gentry)
* Seabirds (R. Day)
* Salmonids (S. Ignell, others)
* Albacore (M. Laurs, R. Lynn)

(7) Approaches to driftnet by-catch estimation (J. Wetherall)

Wednesday, 11 May - Friday, 13 May
8:30 a.m. - 4:30 p.m.

(8) Strategic planning for research (D. Mackett, S. Jacobson, group)
- * overview of planning process
- * discussion of research objectives
- * discussion of "trigger questions"
- * group generation of research projects in response to trigger question
- * clarification of research projects
- * voting & selection of key projects
- * specification of logical relationships among projects
- * flowcharting
- * identification of project activities
- * wrap-up

(9) Discussion of follow-up events & schedule for plan implementation

(10) Adjournment

APPENDIX C

Projects Identified in Response To the Trigger Question

Trigger question:

"In the context of producing a research plan for the SQUADCOM [Squid Advisory Committee], what important projects or major tasks do you think need to be carried out to meet the program objectives by 1994?"

Projects:

1. Develop a model to predict temporal and spatial distribution of squid driftnet effort.

2. Develop an administrative structure for the overall direction of the program.

3. Collect physical oceanographic observations using research vessels, satellites, and meteorology directed toward the subarctic frontal zone.

4. Develop a sampling design, sampling protocols, and an operational plan for an observer program to collect oceanographic, biological, and by-catch data.

5. Estimate the number of marine mammals, seabirds, salmonids, albacore, and other marine resources of the United States (MRUS) killed by driftnets.

6. Determine the causes of incidental mortalities to marine mammals, seabirds, salmonids, albacore, and other MRUS.

7. Understand biological and oceanographic processes affecting the distribution, abundance, and availability of MRUS and their associated catch rates in the driftnet fishery.

8. Develop a research vessel plan to provide data that can be extrapolated. [included in project 27]

9. Estimate trends in the abundance of by-catch species and in the values of relevant biological parameters.

10. Determine where extreme effects occur in the by-catch.

11. Understand effects of mesoscale physical and biological processes on the distribution of squid. [included in project 16]

12. Identify nonfishing factors that influence total abundance and availability of MRUS.

13. Describe inter- and intra-annual variations in the oceanography of the North Pacific Transition Zone and Subarctic Frontal Zone by using historical data, including remote sensing.

14. Develop models of squid population dynamics.

15. Develop a coordinating body for integrating fishery-independent research programs, projects, and initiatives.

16. Understand the effects of mesoscale physical and biological processes on the distribution of important marine resources affected by the squid driftnet fishery.

17. Determine the seasonal and subregional importance of the SAFZ to apex predators.

18. Identify age, sex, reproductive condition, diet, and stock structure of marine mammals, seabirds, salmonids, albacore, and other MRUS caught in the squid driftnet fishery.

19. Describe trophic interrelationships.

20. Define the means of implementing the observer program.

21. Determine how fishing methods affect by-catch.

22. Locate squid spawning grounds and determine spawning seasons.

23. Understand causes of biological patchiness and develop statistical models to describe it.

24. Estimate the "natural variability" of productivity, recruitment, and age structure of species affected by the driftnet fishery.

25. Evaluate North Pacific oceanographic monitoring capabilities and establish/recommend improvements.

26. Estimate drop out, survival, and discard rates for albacore and other important MRUS.

27. Develop research program options, including research vessel plans, to estimate total incidental mortalities in the absence of adequate observer agreements.

28. Estimate survival rates of animals that drop out of the net or are discarded. [included in project 26]

29. Determine physical and biological causes of inter-annual variation in abundance of seabirds and other apex predators.

30. Measure proximate factors (e.g., movement and dive patterns) that place marine mammals at risk.

31. Evaluate the independence of the stocks of impacted species.

32. Determine stock origins of by-catch species. [included in project 31]

33. Acquire reliable information on the distribution of fishing effort.

34. Determine how squid migrations are directed and facilitated.

35. Check assumptions and applicability of current statistical models to the real ocean.

36. Describe and explain similarities and differences in the scale of biological and physical oceanographic events in the North Pacific.

37. Identify and define habitats and distributions of MRUS affected by drift gill-net fisheries.

38. Develop criteria for impact assessment of important MRUS.

39. Establish analytical and data management support for by-catch estimation program.

40. Develop an understanding of market factors and operations that drive the squid fishery.

41. Understand the biological importance of Subtropical Frontal Zone to flying squid and other species.

42. Understand the vertical segregation of squid and other species with respect to oceanographic conditions, season, and geographic area.

43. Develop models to predict by-catch under various scenarios of the squid driftnet fishery.

44. Collect information on the amount and distribution of marine debris in the North Pacific and its impact on MRUS.

45. Determine depth distribution of squid and by-catch species at night on the fishing grounds. [included in project 42]

46. Develop a mechanistic explanation for the dynamics of drift net fisheries.

47. Evaluate the socioeconomic impacts of foreign drift gill-net fisheries on the United States.

48. Develop gear modifications to reduce the entanglement of marine mammals, seabirds, salmonids, albacore, and other important MRUS.

49. Review national and international laws, policies, and agreements regarding high-seas fisheries resource utilization.

50. Develop technologies to reduce biological impacts of abandoned, lost, or discarded fishing gear.

51. Determine overlap in the ocean distribution of flying squid and salmonids during different seasons.

52. Determine distribution patterns of major prey of marine mammals, seabirds, flying squid, salmonids, albacore, and other MRUS.

53. Determine distribution patterns of the major prey of squid and seabirds. [included in project 52]

54. Establish a clearinghouse for oceanographic data, so that they are readily available to investigators.

55. Compile historical biological and oceanographic survey data and add to the data base.

56. Establish oceanographic sampling protocols for observers, including what should be measured, standardization of methods, and sampling design. [included in project 4]

57. Establish biological sampling protocols for observers, including what should be measured, standardization of methods, and sampling design. [included in project 4]

58. Explore means for obtaining baseline data on flying squid and by-catch species.

59. Develop methods of following and interpreting trends in potential stock size and body size composition in flying squid and by-catch species.

60. Develop or explore uses of other types of fishing gear.

61. Develop instrumentation to facilitate investigations of biological and oceanographic processes.

62. Correlate fishing effort information with oceanographic factors.

63. Evaluate the socioeconomic value of the squid driftnet fishery to harvesting nations.

APPENDIX D

Preliminary List of Tasks and Activities Required to Complete the Projects

Administration

Projects Pertaining to This Section:

2. Develop an administrative structure for the overall direction of the program.

15. Develop a coordinating body for integrating fishery-independent research programs, projects, and initiatives.

27. Develop research program options, including research vessel plans, to estimate total incidental mortalities in the absence of adequate observer agreements.

Activities Required to Initiate and Complete Project 27:

See Oceanography Section

Activities Required to Initiate and Complete Projects 15 and 2:

1. Identify projects and potential contributors, such as university scientists, that are needed for the program.

2. Prepare a comprehensive research proposal for internal review. The proposal should include means of accomplishing some research objectives through ongoing projects, thereby acquiring information at either no cost or, with minor adjustments to fieldwork, a small additional cost.

3. Develop an international committee of scientists to deliberate, recommend, and initiate research activities independent of current research programs.

4. Assess the viability, suitability, and potential structure of a multilateral body to coordinate research activities.

5. Develop specific terms of reference for the international coordinating body.

6. Develop program management options for review and discussion by appropriate National Marine Fisheries Service (NMFS) regional administrators and science directors. Such options would include task leadership, advisory structure, location of research activities, and funding sources.

7. Initiate administrative actions to put the structure in place, including development of position descriptions, administrative orders, Current Year Operating Plans, supplemental funding requests, and reprogramming memoranda.

8. Hold program review for an in-house NMFS advisory committee every 2 years and explicitly identify areas and projects that could benefit other ongoing NMFS programs. Involve industry and other pertinent constituents in the review.

9. Prepare and deliver annual report to Congress as required by the Driftnet Act of 1987 (Public Law 100-220, Title IV) and all other deliverables required by that law.

10. Explore the feasibility of an international industry-government observer program for North Pacific high-seas fisheries.

Oceanography

Projects Pertaining to This Section:

4. Develop a sampling design, sampling protocols, and an operational plan for an observer program to collect oceanographic, biological, and by-catch data.

7. Understand biological and oceanographic processes affecting the distribution, abundance, and availability of MRUS and their associated catch rates in the driftnet fishery.

13. Describe the inter- and intra-annual variations in the oceanography of the North Pacific Transition Zone and Subarctic Frontal Zone by using historical data, including remote sensing.

16. Understand the effects of mesoscale physical and biological processes on the distribution of important marine resources affected by the squid driftnet fishery.

22. Locate squid spawning grounds and determine spawning seasons.

23. Understand causes of biological patchiness and develop statistical models to describe it.

27. Develop research program options, including research vessel plans, to estimate total incidental mortalities in the absence of adequate observer agreements.

37. Identify and define habitats and distributions of MRUS affected by drift gill-net fisheries.

<u>Activities Required to Initiate and Complete Project 4</u>:

See Fishery Monitoring and Analysis Section

<u>Activities Required to Initiate and Complete Project 27</u>:

1. Identify domestic and foreign resources (e.g., dollars, ship time, data, scientists, satellites, established research programs) that are potentially available and applicable to this problem.

2. Develop a "white paper" on the full costs (dollars and otherwise) of obtaining by-catch information through either an observer program or a research vessel survey program.

3. Convene a workshop of involved parties to address the questions of research objectives, cruise plans, field methodology, data management, analysis, reporting, coordination of field activities, and cross-fertilization.

4. Agree on a matrix of actions.

5. Develop a predictive and mechanistic models of by-catch. Specifically: (a) using research vessel data and observer data, describe and quantify the relationships between by-catch rates and oceanographic parameters; (b) using observer data, establish the behavior and dynamics of the fishery and assess the importance of oceanographic features to the selection of fishing areas; (c) develop an ocean monitoring capability using satellites, "ships of opportunity," the Shipboard Environmental (Data) Acquisition System expendable bathythermograph program (XBT), and other elements to describe frontal structure and sea surface temperature mesoscale patterns; (d) allocate fishing effort throughout the fishing region according to information in (b) and relate this to (c), then predict the catch from models developed in (a); (e) test and verify (d) by using observer data and information from chartered commercial squid vessels.

6. Design and conduct a research cruise, including squid jigging, acoustic surveys, and sighting surveys of marine mammals and seabirds in Subarctic Frontal Zone waters during the North Pacific squid driftnet fishing season.

7. Review and assess the economic performance of the squid driftnet fishery. If possible, use historical data to analyze the association (e.g., regression) between target catch levels and by-catch levels and to estimate the current level of by-catch.

8. Obtain by-catch information from foreign governments or fishing associations.

9. Assess the suitability of research vessel operations for estimating driftnet by-catch rates in lieu of broad commercial vessel observer coverage. What are the shortcomings of this approach? Under what conditions would it be an acceptable alternative?

10. Begin work in 1988 to design cooperative research surveys with Taiwan, Japan, and Korea to address this project.

11. Initiate discussions, through nongovernmental channels, with scientists from the drift-netting nations to develop coordinated international research efforts. In these discussions, promote the deployment of research vessels in areas of critical interest. Some important steps are (a) identify the data needed to meet the objective; (b) decide what sampling gear, survey patterns, station placement, etc. are required to satisfy by-catch estimation requirements; (c) define the best composition of field parties for the surveys; (d) decide how the survey data will be shared, managed, analyzed, and reported.

<u>Activities Required to Initiate and Complete Project 22</u>:

1. Describe the reproductive biology of important squid species.

2. Review information on the spawning characteristics of squid and the oceanographic features of known or assumed spawning regions to identify oceanographic parameters associated with preferred spawning grounds (e.g., the intensity, depth, and variability of the subsurface salinity maximum).

3. Review information on the physical oceanography of the North Pacific Transition Zone and the Subtropical Frontal Zone to determine places and times suitable for spawning of flying squid. Describe the hydrostatic stability distribution in the Subtropical Frontal Zone, so that areas of high stability can be mapped (if the high stability layer is too deep or nonexistent, squid eggs may sink into unfavorably deep waters).

4. Survey likely spawning areas and "control" areas with plankton nets to estimate the density of squid paralarvae.

5. Survey central Pacific waters north of Hawaii and waters in the eastern part of the North Pacific Transition Zone for squid larvae and juveniles during the winter and spring.

6. Once spawning grounds are located, examine seasonal variation in the abundance of paralarvae and determine precise physical correlates.

7. Attempt to track several maturing squid by using acoustic tags.

8. Examine stomachs of seabirds for the presence of juvenile squid as an indication of juvenile squid distribution.

9. Design and conduct a tag and release experiment to determine flying squid spawning migration patterns.

10. Determine the lifespan of flying squid and what proportion of females spawn during their second year.

11. Determine the number of distinct spawning populations.

12. Involve Japanese, Korean, and Taiwanese scientists at all stages, especially in the initial planning stages where their knowledge and experience would be vital, and in cooperative research vessel surveys.

13. Determine what data, e.g., biological samples or observations, could be collected from the commercial fishery that would be helpful.

Activities Required to Initiate and Complete Projects 37 and 7:

1. Conduct a complete review of available literature on the habitats, abundance, and distributions of important MRUS.

2. Define important/key processes affecting MRUS.

3. For those MRUS caught in the squid driftnet fisheries, collect and correlate catch rate data and any other available information on abundance, distribution, and movements with biological and physical oceanographic data (including satellite data) by season and age. Determine whether these associations change over time and area.

4. Identify gaps in knowledge and set up research programs to fill them. For stocks and life history stages about which little is known, conduct a "course grain" survey involving measurement of many physical and biological oceanographic factors in areas where the particular resource is known or thought to occur.

5. Using commercial driftnet gear, conduct research vessel fishing operations over a prescribed area following a predetermined sampling plan. In particular (a) measure seasonal distributions and abundance of key MRUS in the squid fishing area (for seabirds and marine mammals, use at-sea transects; for fishes, cephalopods, and sea turtles, use standardized fixed fishing stations); (b) measure physical oceanography (current structure, water-column structure, temperature-conductivity profiles, water clarity) and biological oceanography (patterns of primary production, zooplankton densities, densities of squid and smaller fishes that may be eaten by the larger MRUS) in the squid fishing area concurrently [mesoscale and possibly microscale]; and (c) try to relate (a) and (b). As part of this study, determine the "availability" of MRUS to squid driftnets by measuring depths in the water column at which MRUS species occur while in the squid fishing area, and depths at which the prey of MRUS occur. Measure these at all appropriate scales and conduct the physical and biological sampling year-round to determine seasonality.

6. Determine the association between marine mammal and seabird diving activity and oceanographic features, particularly the location and strength of temperature and/or salinity fronts, where squid are taken by the fishery.

7. Examine the timing of MRUS migrations and movements in relation to temperature fronts, changes in primary productivity, and other factors.

8. Develop a list of research objectives that might be addressed by squid driftnet vessel observers or scientists on research vessels, including the following: (a) determine the variability in depth distributions of important MRUS (e.g., are salmon concentrated in the temperature minimum layer during the summer, below the warmer surface waters where the squid driftnets are fished?); (b) determine the depths at which MRUS are caught in driftnets; (c) make concurrent measurements of MRUS distributions and environmental conditions; (d) conduct environmental-physiological research on MRUS species; (e) determine the extent to which important MRUS alter the course of their direct movement in response to mesoscale oceanographic events.

9. Design means (e.g., using satellite data) for monitoring key environmental processes.

10. Study the distribution and abundance of prey resources.

<u>Activities Required to Initiate and Complete Project 13</u>:

1. Examine Color Zone Color Scanner imagery and Advanced Very High Resolution Radiometer data from the North Pacific for gradients and determine mesoscale and fine-scale spatial patterns of "chlorophyll" and sea surface temperature within high-gradient regions.

2. Inventory historical oceanographic data and develop a data management system as required. Examine historical data to determine medians and ranges of important parameters. Incorporate these statistics into the data base.

3. Examine marine deck sea surface temperature, winds, and derived physical quantities for seasonal and longer term variations in regions of the North Pacific Transition Zone.

4. Investigate the effect of atmosphere forcing on the spatial and temporal variability of the North Pacific Transition Zone and associated frontal zones with a grid mesh no coarser than 1° of latitude and 1° of longitude.

5. Relate mesoscale eddies to the position of larger scale fronts in areas of current confluence.

<u>Activities Required to Initiate and Complete Projects 16 and 23</u>:

1. Design and conduct a focused mesoscale experiment, including (a) locating regions of larger scale confluences (fronts), initially using satellite infrared data; (b) mapping the eddy field in the confluence region; (c) mapping the thermohaline structure in the upper few hundred meters (to determine variability of stratification); (d) mapping the flow field using acoustic Doppler current profilers (while vessel is under way); (e) mapping the chlorophyll-*a* structure (in conjunction with a towed instrument, such as a conductivity-temperature-depth (CTD) recorder); and (f) replication of all survey tracks.

2. In a critical region of the squid gill-net fishery, design and execute a mesoscale experiment to map mesoscale biological and physical patchiness (areas of convergence of large-scale currents are favorable for this). Objectives of the experiment would be to (a) describe spatial scales in the patchiness of important food organisms for fishes, squid, marine mammals, and seabirds; (b) relate spatial scales of biological patchiness to dominant scales of physical oceanographic structure; (c) examine primary productivity and zooplankton biomass throughout mesoscale eddies in the squid fishing area; (d) take samples on different spatial scales from a region so that it is possible to determine whether the distribution of patches is random or uniform (do this for both biological and physical variables); and (e) identify and develop appropriate statistical models for analyzing the data.

3. Define key mesoscale processes affecting the distributions of MRUS, by conducting research vessel cruises to the Subarctic Frontal Zone. Such surveys should include the following: (a) biological and oceanographic sampling stations situated approximately 25 km apart along meridional transect approximately 50-100 km apart (the sampling region should be selected to include mesoscale eddies); (b) oceanographic sampling with CTD casts and calibration (sea-truthing) of CTD's with Nansen or Niskin bottles; (c) biological sampling with drift gill nets, hydroacoustic gear, midwater trawls, and plankton nets; (d) analysis of stomach contents of nekton caught in the various nets; and (e) attachment of instruments to track spatiotemporal movements of key MRUS.

4. Compare research and commercial vessel catch results with mesoscale features identified by satellite data (color analysis, sea surface temperature, and flow patterns).

5. Carry out experiments to determine the response of key MRUS to variations in those physical parameters most often used to identify and describe mesoscale oceanographic events.

<u>Fishery Monitoring and Analysis</u>

<u>Projects Pertaining to This Sector</u>

1. Develop a model to predict temporal and spatial distribution of squid driftnet effort.

4. Develop a sampling design, sampling protocols, and an operational plan for an observer program to collect oceanographic, biological, and by-catch data.

5. Estimate the number of marine mammals, seabirds, salmonids, albacore, and other MRUS killed by driftnets.

6. Determine the causes of incidental mortalities to marine mammals, seabirds, salmonids, albacore, and other MRUS.

9. Estimate trends in the abundance of by-catch species and in the values of relevant biological parameters.

14. Develop models of squid population dynamics.

20. Define the means of implementing the observer program.

22. Locate squid spawning grounds and determine spawning seasons.

27. Develop research program options, including research vessel plans, to estimate total incidental mortalities in the absence of adequate observer agreements.

43. Develop models to predict by-catch under various scenarios of the squid driftnet fishery.

<u>Activities Required to Initiate and Complete Projects 22 and 27</u>:

See Oceanography Section

<u>Activities Required to Initiate and Complete Projects 6 and 9</u>:

See Biology Section

<u>Activities Required to Initiate and Complete Projects 43 and 1</u>:

1. Obtain historical squid fishing effort data to (a) develop a statistical model of effort incorporating sea surface temperature, squid catch per unit effort (CPUE), latitude, longitude, season, and year effects and (b) examine interannual variability in effort as a function of season, area, and sea surface temperature.

2. Determine what fishery information should be requested from governments of driftnet nations and collected by observers.

3. Establish a cooperative program on fishery assessment with Korea, Taiwan, and Japan.

4. Determine which research vessel data would be useful in predicting by-catches.

5. Analyze available observer data on by-catch rates to estimate effects of area, season, and oceanographic conditions. Look for between-species associations in by-catch rates.

6. Examine the southern distribution of salmonids relative to sea surface temperature and latitude in the squid fishing area.

7. Evaluate nonfishery information for its importance in predicting by-catch levels. For example, the world catch of squid by Japan and squid import levels in Japan may be important variables to monitor, as major changes in them might affect effort in the North Pacific squid driftnet fishery and by-catch levels.

8. Develop models based on temperature preferences and entanglement rates to predict areas of greatest by-catch levels for various MRUS.

9. Upgrade model with data on horizontal and vertical gradients in temperature that affect availability of MRUS.

10. Evaluate Japanese models for preseason and within-season squid fishery forecasts.

11. Develop models to predict catch and effort for the next fishing season.

<u>Activities Required to Initiate and Complete Project 14</u>:

[Note: The activities listed below assume a broader project objective, incorporating not only squid population dynamics but also the population dynamics of all important MRUS.]

1. Search literature on the species of interest to obtain available information required for modeling population dynamics.

2. Identify MRUS requiring population dynamics modeling.

3. Determine what kinds of fishery data need to be collected for MRUS (including squid) and the best means of collecting them.

4. Collect basic biological data, such as growth rates, age structure, age at maturity, sex ratios, and food habits required to develop models for each MRUS species.

5. Compile and analyze available data on trends in squid CPUE and size composition by using Japanese, Korean, and Taiwanese fishery data. Evaluate interannual variability in squid recruitment and growth.

6. Determine the most appropriate population dynamics models for each MRUS species. Look at cross- and autocorrelations in time series of population characteristics to determine important dependencies and time lags. Develop multispecies models and identify functional relationships between model components. Estimate parameters and carry out sensitivity analyses.

7. Develop models to assess interspecific interactions among impacted MRUS, both those affected directly by driftnet mortality and those affected indirectly.

8. Develop autoregressive models of squid stock dynamics by using CPUE and size-frequency data.

9. Develop models describing how stock dynamics respond to changes in oceanographic conditions.

10. Obtain information from Japanese scientists regarding their fishery "production models." What kinds of models do they use? How do they apply them?

11. Convene an international conference of the biology of flying squid (Japan might be the best venue).

<u>Activities Required to Initiate and Complete Project 20</u>:

1. Negotiate with nations having driftnet fleets to establish agreements for acceptance and deployment of observers.

2. Initiate a coordinated, international observer program including observers from Japan, Korea, and Taiwan.

3. Draft an observer plan to provide data necessary for estimating the numbers of MRUS killed by driftnets.

4. Establish a way to fund the observer program.

5. Determine observer program staffing requirements and budget.

6. Develop an observer program package and strategic plan and present them to NMFS administrators, including west coast Regional Directors.

7. Decide who will be responsible for implementing and administering the observer program.

<u>Activities Required to Initiate and Complete Project 5</u>:

1. Determine which MRUS killed by driftnets are highest priority for observations on commercial vessels, by time and area.

2. Determine the total squid driftnet effort level and the distribution of effort in each year.

3. Develop methods to estimate the mortality rates attributable to driftnet entanglement for MRUS that drop out of the driftnets during retrieval, escape from the nets while they are soaking, or are released after being taken aboard.

4. Identify the types of observer data required to estimate MRUS incidental mortalities accurately and reliably.

5. Initiate the observer program.

Activities Required to Initiate and Complete Project 4:

1. Develop a systematic approach to modeling driftnet effort, including (a) determining the level of observer coverage and sampling required (and associated costs); (b) determining the level of fishing effort and its distribution by time and area; (c) determining the total catch and CPUE from the effort distribution; (d) relating catch, CPUE, and effort to oceanographic conditions, season, and area; (e) determining critical seasons and areas associated with the largest impacts on MRUS; and (f) using data from past observer cruises, determine sampling variances within and between vessels.

2. Define and prioritize ocean measurements that should be made by observers and specify appropriate methods and instruments.

3. Review instrumentation capabilities of available observer platforms, including CTD and XBT systems.

4. Determine what biological measurements and samples can be taken from by-catch specimens and whether or not biological samples, such as stomach contents, can be analyzed at sea.

5. Design a sampling strategy specifying where, when, and how many measurements should be made.

6. Develop a streamlined data logging procedure compatible with computer data processing systems.

7. Develop an observer manual, training procedures, and training materials that will enable observers to identify all fishes, cephalopods, seabirds, sea turtles, and marine mammals likely to be seen or entangled in the driftnet fishing area.

8. Use observer data to ground-truth oceanographic measurements made from remote platforms.

9. Instruct observers to take frequent measurements of sea surface temperature, possibly supplemented by XBT drops, and to note events or conditions indicating ocean frontal structure (e.g., debris, change in water color).

Biology

Projects Pertaining to This Section:

6. Determine the causes of incidental mortalities to marine mammals, seabirds, salmonids, albacore, and other MRUS.

7. Understand biological and oceanographic processes affecting the distribution, abundance, and availability of MRUS and their associated catch rates in the driftnet fishery.

9. Estimate trends in the abundance of by-catch species and in the values of relevant biological parameters.

12. Identify nonfishing factors that influence total abundance and availability of MRUS.

14. Develop models of squid population dynamics.

18. Identify age, sex, reproductive condition, diet, and stock structure of marine mammals, seabirds, salmonids, albacore, and other MRUS caught in the squid driftnet fishery.

19. Describe trophic interrelationships.

24. Estimate the "natural variability" of productivity, recruitment, and age structure of species affected by the driftnet fishery.

37. Identify and define habitats and distributions of MRUS affected by drift gill-net fisheries.

<u>Activities Required to Initiate and Complete Project 14</u>:

See Fishery Monitoring and Analysis Section

<u>Activities Required to Initiate and Complete Project 37 and 7</u>:

See Oceanography Section

<u>Activities Required to Initiate and Complete Project 6</u>:

1. Determine patterns of behavior of MRUS that affect their catch rates in driftnets (e.g., vulnerability or catchability). Specifically: (a) study the behavior and positioning of seabirds and marine mammals around driftnet vessels and their gear during net retrievals to determine which are "active participants" and which are "observers;" (b) estimate seabird and marine mammal attraction rates during driftnet deployment and retrieval and determine which species are attracted most strongly; (c) deploy instruments (e.g., satellite tracking beacons, mini-CTD probes, or time-depth recorders) on marine mammals in the squid fishing area to determine their movements within the area, and possibly their dive patterns, for comparison with distributions of fishing effort and entanglement rates; (d) study acoustic and visual capabilities of cetacean species subject to driftnet entanglement and develop models of net detection mechanisms; (e) determine the vertical and horizontal distributions of MRUS throughout the driftnet fishing season.

2. Evaluate information on food habits of MRUS.

3. Determine the degree to which driftnet catches attract predators, i.e., are the entanglement rates of sharks, marine mammals, or other larger MRUS greater in nets that have caught more squid and smaller fish?

4. Conduct 24-hour scuba observations on soaking driftnets to examine hypotheses on the so-called "net community." Specifically, map the microscale physical environment around the net (e.g., water movement) that may influence the development and persistence of a net-associated biological community and determine the composition, distribution, and aggregation of "baitfish" and microorganisms. Consider the effects of single driftnets versus those set in "net arrays."

5. Determine what types of information (e.g., behavioral observations, oceanographic data, and catch data) should be collected by driftnet fishery observers to improve the understanding of entanglement causes.

6. Review and develop models of squid gill net selectivity for various MRUS.

7. Determine the effects of age and sex on the catchability of by-catch species.

8. Determine the diel vertical migration patterns of fish and squid caught in the driftnets.

9. Determine the vertical and horizontal position of entanglement in the driftnets, for various MRUS.

10. Summarize present information on the geographical distribution of MRUS in relation to driftnet fishing effort and identify data gaps in this area.

11. Experiment with subsurface gill nets, i.e., with deployment of surface driftnets several meters deeper than usual.

<u>Activities Required to Initiate and Complete Projects 9 and 12</u>:

1. Determine what nations and agencies have current programs to estimate and monitor the abundance of MRUS.

2. Determine habitat requirements and biological limitations of MRUS and relate these to actual conditions in the driftnet fishing area on a seasonal basis.

3. Develop scientifically appropriate methods of monitoring long-term population trends of key MRUS by-catch species and establish monitoring programs.

4. Determine seasonal and geographical changes in the distribution and abundance of MRUS.

5. Determine the distribution and abundance of MRUS in relation to physical and biological conditions over time and area.

6. Determine the distributions of important MRUS prey resources and variations in the availability of prey by time and area.

7. On a smaller temporal scale, determine the distributions of MRUS prey species over the soak time of the driftnets.

8. Get catch data from driftnet fishing nations as part of agreements on scientific cooperation and exchange.

9. Compute by-catch rates by area, season, and sea surface temperature and determine whether the rates are declining due to driftnet effort or other factors.

10. Evaluate interannual variation in CPUE and by-catch. Examine long-term trends. Note that oceanographic conditions may make a species move into or out of the fishery area in a given year, thereby affecting catch rates.

11. Conduct sighting surveys or censuses over the driftnet fishing grounds and/or the range of key marine mammal and seabird species to estimate levels of abundance and trends over time.

12. Collect biological samples annually from incidentally taken marine mammals and other MRUS and analyze changes in parameters such as age at first reproduction, body length, age structure, and reproduction rate.

13. Determine the natural mortality rates of key MRUS species.

14. Establish long-term programs to monitor populations at breeding colonies of marine mammals, seabirds (especially Laysan albatross), and sea turtles.

15. Analyze trends in the abundance of important MRUS. Some specific research activities that would be needed are: (a) correlate northern fur seal abundance trends with gill net/pollock and other fisheries; (b) examine catch rate and size composition data for blue sharks taken in the driftnets (this may one of the first MRUS to show a decline in abundance due to its low reproductive potential and frequency of occurrence in driftnet catches); (c) develop an index of stock size for albacore; (d) examine size-at-age trends for pomfret using Japanese data; (e) evaluate growth increments on statoliths of squid to estimate growth rates and stock differences; (f) determine species and stock composition of salmonids important to fishery.

<u>Activities Required to Initiate and Complete Project 18</u>:

1. Collect biological samples from MRUS caught by research vessels and commercial vessels, including teeth (from seals and other marine mammals), stomachs, reproductive organs, hard parts (scales for salmonids; otoliths, vertebrae, or spines for tunas and billfishes; statoliths for cephalopods), and blood; identify sex, reproductive condition, and body length; collect skulls of marine mammals to determine whether immature/subadult or adult.

2. Define criteria for determining structure and identity of MRUS populations (or stocks), and determine mixing rates between populations.

3. Assess the usefulness of various stock identification (ID) techniques (e.g., scar characteristics, morphometrics, genetic variation using electrophoretic DNA analysis, or differences in parasite assemblages.

4. Apply stock ID techniques to identify stock composition of MRUS taken in the driftnet catch from subsamples of the catch.

5. Determine statistical criteria and appropriate sampling rates to accomplish the stock structure assessments.

6. Determine the spatial boundaries for each population, and describe associated physical oceanographic and biological characteristics of the habitat.

Activities Required to Initiate and Complete Project 19:

1. Review literature to see what is known about food habits and potential distributional overlap of MRUS.

2. Collect stomach samples from target and by-catch species by season, area, and time of day or night, and analyze them to estimate species composition of prey and time and depth of prey ingestion.

3. Determine the depth distribution of important prey resources, particularly during night.

4. Estimate seasonal changes in the abundance of prey items by area and establish causes for seasonal shifts of prey distribution.

5. Measure the impacts on MRUS of marine debris that is ingested and determine the characteristics of plastic debris that is ingested.

6. Study the selectivity process in seabird and marine mammal foraging using trawls or remotely operated vehicles. Consider deploying video systems to determine which prey species are present but not consumed by foraging seabirds and marine mammals.

7. Determine prey density and composition in areas where seabirds and marine mammals are <u>not</u> foraging, as well as where they are.

8. Synthesize data into a conceptual "model" that shows trophic levels and interrelationships.

Activities Required to Initiate and Complete Project 24:

1. On an annual basis, estimate the productivity of each MRUS species affected by driftnets or assemble information from other ongoing projects that are doing so.

2. Estimate the fecundity of key MRUS by using information already available and develop plans to collect reproductive tracts as necessary to improve estimates.

3. Verify ageing techniques and collect samples of teeth, scales, otoliths, squid beaks, and other hard parts, as well as length-frequency measurements, from key MRUS taken by commercial and research vessels.

4. For key seabird species, establish colony surveys to monitor population productivity and estimate annual reproductive success.

5. Establish long-term population monitoring to provide basis for measuring variations in recruitment.

6. Measure mortality rates at different life history stages for pertinent stocks of each MRUS species.

List of Figures

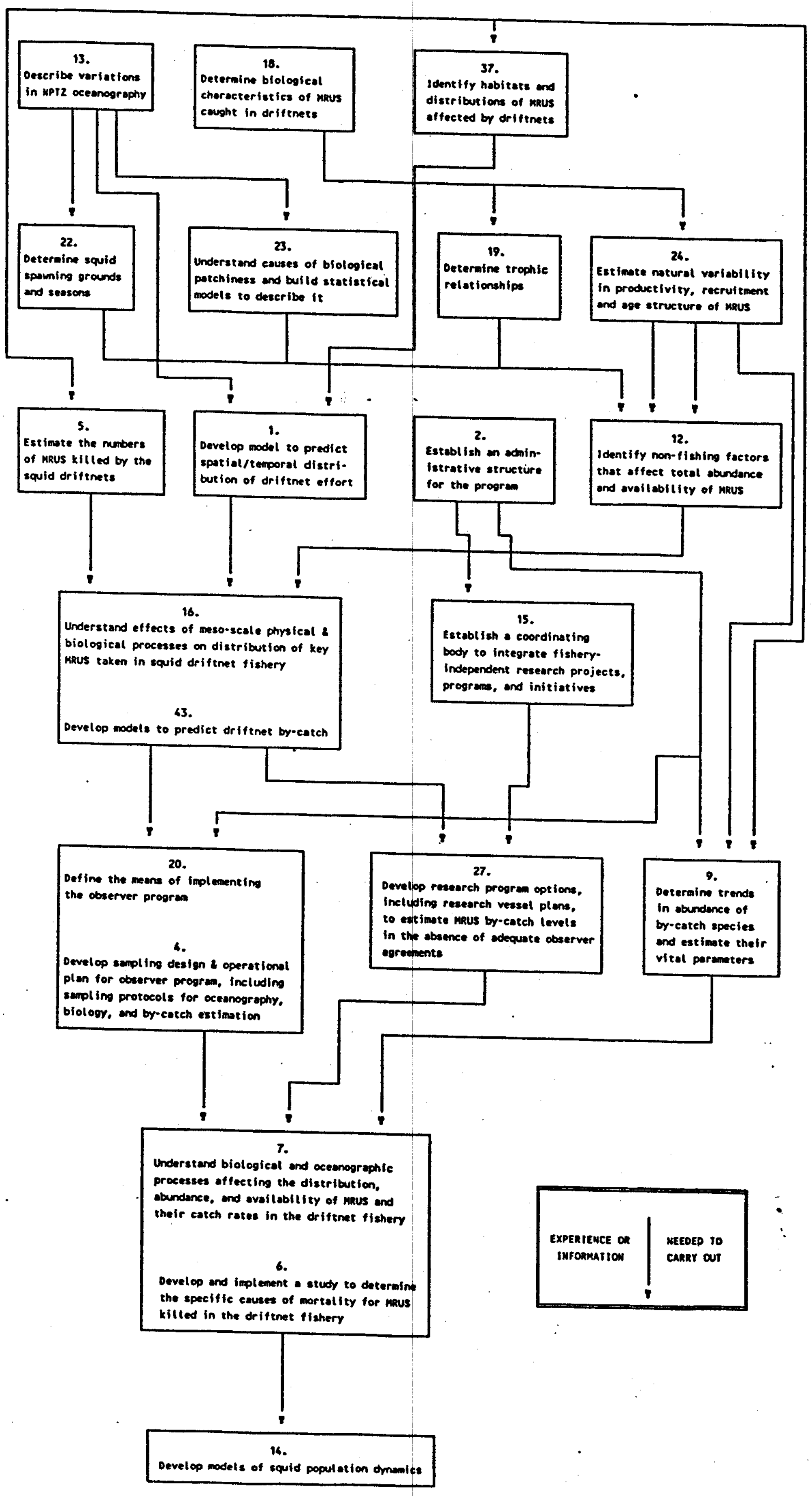
13. Describe variations in NPTZ oceanography
18. Determine biological characteristics of MRUS caught in driftnets
37. Identify habitats and distributions of MRUS affected by driftnets
22. Determine squid spawning grounds and seasons
23. Understand causes of biological patchiness and build statistical models to describe it
19. Determine trophic relationships
24. Estimate natural variability in productivity, recruitment and age structure of MRUS
5. Estimate the numbers of MRUS killed by the squid driftnets
1. Develop model to predict spatial/temporal distribution of driftnet effort
2. Establish an administrative structure for the program
12. Identify non-fishing factors that affect total abundance and availability of MRUS
16. Understand effects of meso-scale physical & biological processes on distribution of key MRUS taken in squid driftnet fishery
43. Develop models to predict driftnet by-catch
15. Establish a coordinating body to integrate fishery-independent research projects, programs, and initiatives
20. Define the means of implementing the observer program
4. Develop sampling design & operational plan for observer program, including sampling protocols for oceanography, biology, and by-catch estimation
27. Develop research program options, including research vessel plans, to estimate MRUS by-catch levels in the absence of adequate observer agreements
9. Determine trends in abundance of by-catch species and estimate their vital parameters
7. Understand biological and oceanographic processes affecting the distribution, abundance, and availability of MRUS and their catch rates in the driftnet fishery
6. Develop and implement a study to determine the specific causes of mortality for MRUS killed in the driftnet fishery
14. Develop models of squid population dynamics
EXPERIENCE OR INFORMATION
NEEDED TO CARRY OUT

Figure 1

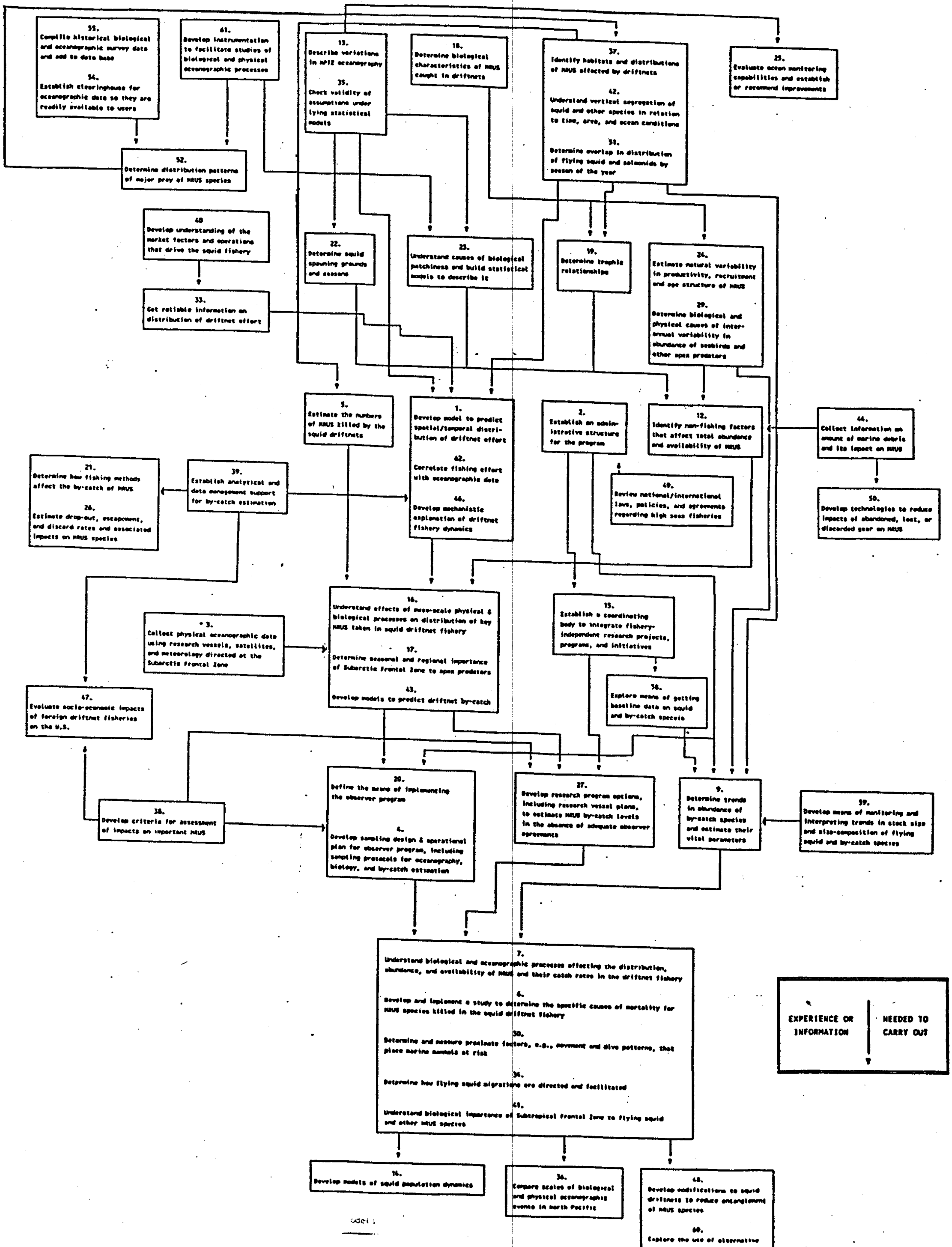
55.
Compile historical biological and oceanographic survey data and add to data base
54.
Establish clearinghouse for oceanographic data so they are readily available to users
61.
Develop instrumentation to facilitate studies of biological and physical oceanographic processes
13.
Describe variations in NPTZ oceanography
35.
Check validity of assumptions underlying statistical models
18.
Determine biological characteristics of MRUS caught in driftnets
37.
Identify habitats and distributions of MRUS affected by driftnets
42.
Understand vertical segregation of squid and other species in relation to time, area, and ocean conditions
31.
Determine overlap in distribution of flying squid and salmonids by season of the year
25.
Evaluate ocean monitoring capabilities and establish or recommend improvements
52.
Determine distribution patterns of major prey of MRUS species
40
Develop understanding of the market factors and operations that drive the squid fishery
22.
Determine squid spawning grounds and seasons
23.
Understand causes of biological patchiness and build statistical models to describe it
19.
Determine trophic relationships
24.
Estimate natural variability in productivity, recruitment and age structure of MRUS
29.
Determine biological and physical causes of inter-annual variability in abundance of seabirds and other apex predators
33.
Get reliable information on distribution of driftnet effort
5.
Estimate the numbers of MRUS killed by the squid driftnets
1.
Develop model to predict spatial/temporal distribution of driftnet effort
62.
Correlate fishing effort with oceanographic data
46.
Develop mechanistic explanation of driftnet fishery dynamics
2.
Establish an administrative structure for the program
12.
Identify non-fishing factors that affect total abundance and availability of MRUS
44.
Collect information on amount of marine debris and its impact on MRUS
21.
Determine how fishing methods affect the by-catch of MRUS
26.
Estimate drop-out, escapement, and discard rates and associated impacts on MRUS species
39.
Establish analytical and data management support for by-catch estimation
49.
Review national/international laws, policies, and agreements regarding high seas fisheries
50.
Develop technologies to reduce impacts of abandoned, lost, or discarded gear on MRUS
16.
Understand effects of meso-scale physical & biological processes on distribution of key MRUS taken in squid driftnet fishery
17.
Determine seasonal and regional importance of Subarctic Frontal Zone to apex predators
43.
Develop models to predict driftnet by-catch
3.
Collect physical oceanographic data using research vessels, satellites, and meteorology directed at the Subarctic Frontal Zone
15.
Establish a coordinating body to integrate fishery-independent research projects, programs, and initiatives
58.
Explore means of getting baseline data on squid and by-catch speceis
47.
Evaluate socio-economic impacts of foreign driftnet fisheries on the U.S.
20.
Define the means of implementing the observer program
4.
Develop sampling design & operational plan for observer program, including sampling protocols for oceanography, biology, and by-catch estimation
38.
Develop criteria for assessment of impacts on important MRUS
27.
Develop research program options, including research vessel plans, to estimate MRUS by-catch levels in the absence of adequate observer agreements
9.
Determine trends in abundance of by-catch species and estimate their vital parameters
59.
Develop means of monitoring and interpreting trends in stock size and size-composition of flying squid and by-catch species
7.
Understand biological and oceanographic processes affecting the distribution, abundance, and availability of MRUS and their catch rates in the driftnet fishery
6.
Develop and implement a study to determine the specific causes of mortality for MRUS species killed in the squid driftnet fishery
30.
Determine and measure proximate factors, e.g., movement and dive patterns, that place marine mammals at risk
34.
Determine how flying squid migrations are directed and facilitated
41.
Understand biological importance of Subtropical Frontal Zone to flying squid and other MRUS species
EXPERIENCE OR INFORMATION
NEEDED TO CARRY OUT
14.
Develop models of squid population dynamics
36.
Compare scales of biological and physical oceanographic events in North Pacific
48.
Develop modifications to squid driftnets to reduce entanglement of MRUS species
60.
Explore the use of alternative gears for catching flying squid

Figure 2

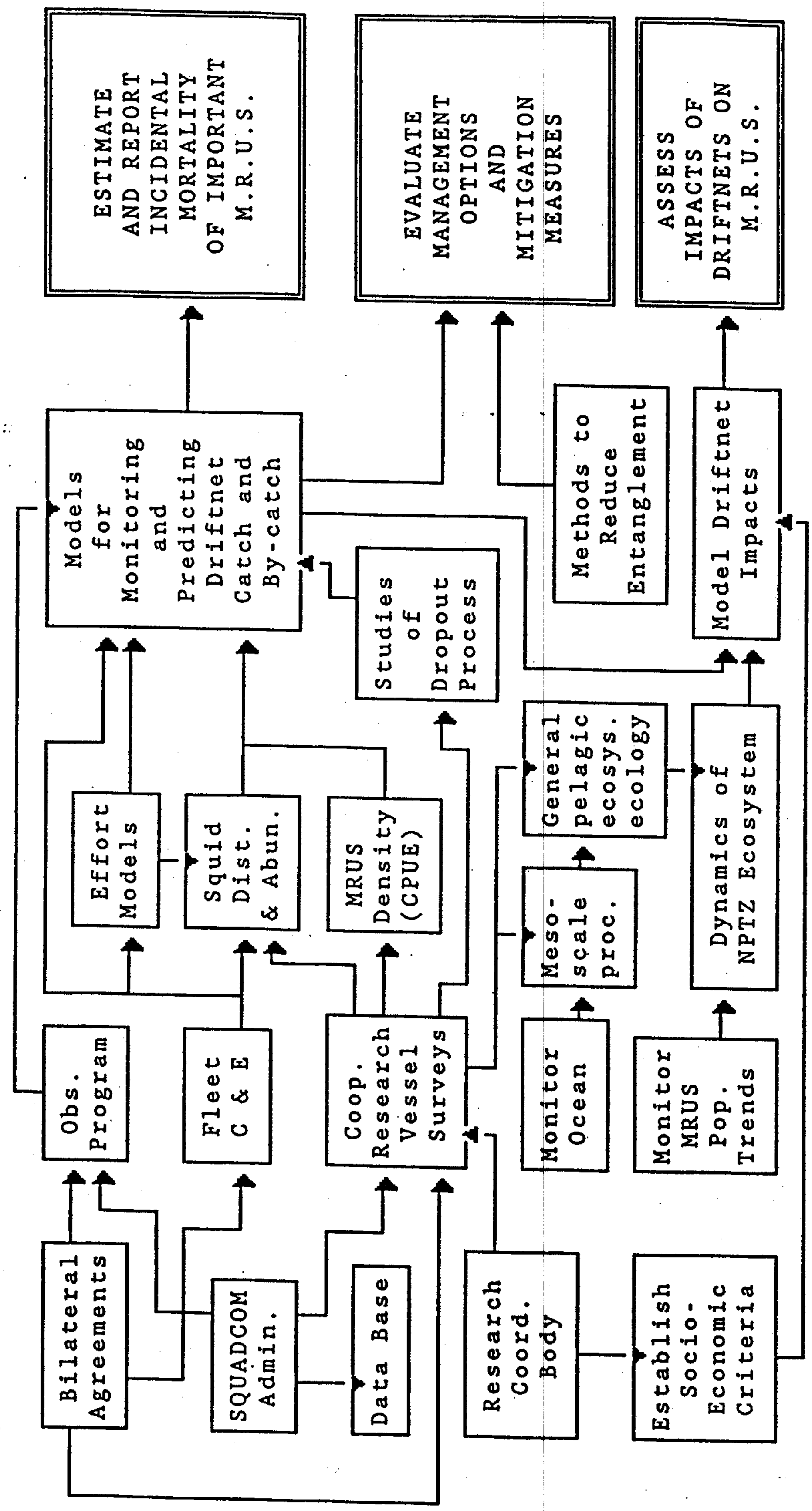
ESTIMATE AND REPORT INCIDENTAL MORTALITY OF IMPORTANT M.R.U.S.
EVALUATE MANAGEMENT OPTIONS AND MITIGATION MEASURES
ASSESS IMPACTS OF DRIFTNETS ON M.R.U.S.
Models for Monitoring and Predicting Driftnet Catch and By-catch
Methods to Reduce Entanglement
Model Driftnet Impacts
Studies of Dropout Process
Effort Models
Squid Dist. & Abun.
MRUS Density (CPUE)
General pelagic ecosys. ecology
Meso-scale proc.
Dynamics of NPTZ Ecosystem
Obs. Program
Fleet C & E
Coop. Research Vessel Surveys
Monitor Ocean
Monitor MRUS Pop. Trends
Bilateral Agreements
SQUADCOM Admin.
Data Base
Research Coord. Body
Establish Socio-Economic Criteria

Figure 3